

REPORT

Expert report, panel 7

Date

October 2021

Panel chair:

Prof. (emer.) Eero Eloranta

Expert report, panel 7

KTH's Research Assessment Exercise (RAE) 2021

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Table of Contents

Introduction	5
Part A: Summary of the whole panel	6
1. Strengths, weaknesses, and recommendations	6
2. Feedback on the formulated visions and strategies	7
3. Ideas and recommendations for essential steps.....	7
4. Potential links and synergies.....	8
5. Recommendations for strengthening the departments and their future potential.....	8
6. Recommendations applicable to the whole of KTH.....	8
Part B: Report for each department.....	10
Department of Sustainable Production Development.....	11
Major findings.....	11
1. Strengths and weaknesses of the department concerned and recommendations for improvement.	11
2. Relevant and forward-looking objectives	11
3. International community engagement	12
4. Future potential of the department.....	12
5. Recommendations	12
Specific issues.....	13
1. Research profile and quality	13
2. Viability and research environment.....	14
3. Strategies and organisation	15
4. Interaction between research and teaching.....	16
5. Impact and engagement in society.....	17
6. Recommendations for strengthening the department and its future potential	17
7. Final remarks.....	18
Department of Industrial Economics and Management	19
Major findings.....	19
1. Strengths and weaknesses of the department.....	19
2. Relevant and forward-looking objectives	19
3. International community engagement	20
4. Future potential of the department.....	20
5. Recommendations	20
Specific issues.....	21
1. Research profile and quality	21
2. Viability and research environment.....	22
3. Strategies and organisation	23
4. Interaction between research and teaching.....	25
5. Impact and engagement in society.....	25
6. Recommendations for strengthening the department and its future potential	26

7. Final remarks..... 27

Department of Learning28

Major findings28

1. Strengths and weaknesses of the department.....28

2. Relevant and forward-looking objectives28

3. International community engagement29

4. Future potential of the department.....29

5. Recommendations29

Specific issues.....30

1. Research profile and quality30

2. Viability and research environment..... 31

3. Strategies and organisation32

4. Interaction between research and teaching.....33

5. Impact and engagement in society.....34

6. Recommendations for strengthening the department and its future potential34

7. Final remarks.....35

Department of Production Engineering36

Major findings36

1. Strengths and weaknesses of the department.....36

2. Relevant and forward-looking objectives37

3. International community engagement37

4. Future potential of the department.....37

5. Recommendations37

Specific issues.....38

1. Research profile and quality38

2. Viability and research environment.....39

3. Strategies and organisation40

4. Interaction between research and teaching.....41

5. Impact and engagement in society.....41

6. Recommendations for strengthening the department and its future potential42

7. Final remarks.....43

Department of Machine Design44

Major findings44

1. Strengths and weaknesses of the department.....44

2. Relevant and forward-looking objectives44

3. International community engagement45

4. Future potential of the department.....45

5. Recommendations45

Specific issues.....46

1. Research profile and quality46

2. Viability and research environment.....47

3. Strategies and organisation	48
4. Interaction between research and teaching.....	48
5. Impact and engagement in society.....	49
6. Recommendations for strengthening the department and its future potential	50
7. Final remarks.....	50

Introduction

This expert panel report is part of the Research Assessment Exercise (RAE) 2021 at KTH Royal Institute of Technology. The report is based on the self-evaluation on panel 7 and aims to provide recommendations and feedback to the involved departments and KTH.

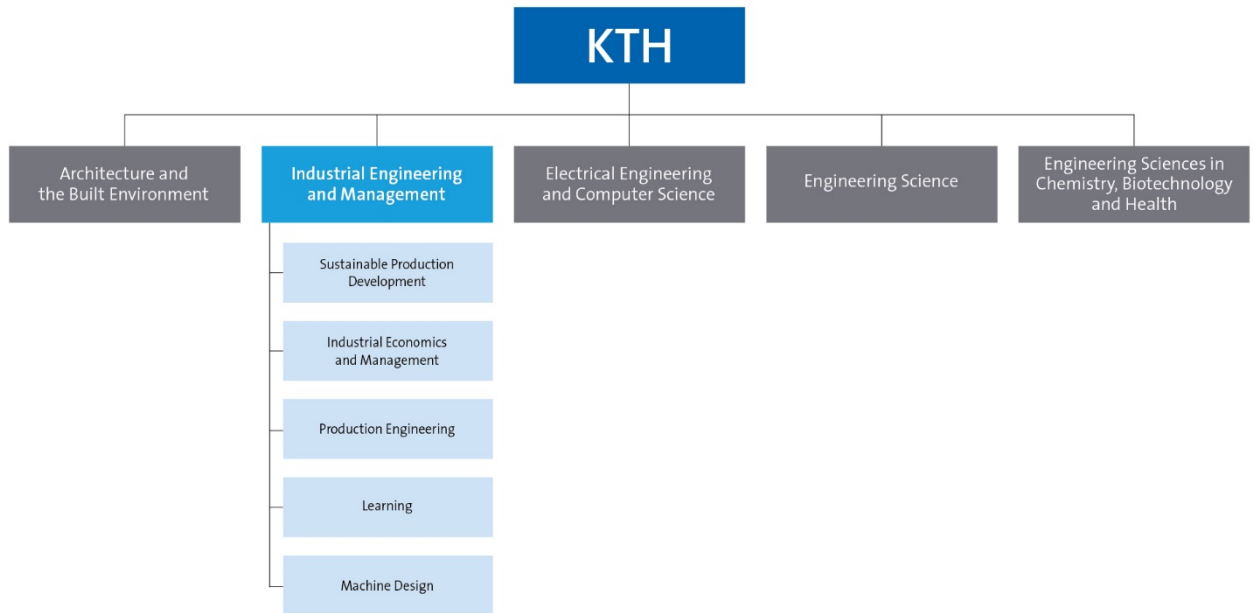
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Panel 7

Coordinator: [Prof. Lihui Wang](#), KTH Royal Institute of Technology

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Part A: Summary of the whole panel

1. Strengths, weaknesses, and recommendations

The five reviewed departments (here called HPU, INDEK, IIP, LES and MMK) have substantial *strengths*, which consistently support the changes in industry and society. Firstly, the research carried out at the five departments is relevant and meaningful for industry and the public sector. The research agenda of each department is built on the context of each discipline so that summing up the departments the composition is synergic. This provides a favourable starting position for future cross-departmental collaboration. Research is run jointly with external partners, large and small as well as private and public. Most partnerships have long traditions and successful continued collaboration. Naturally, the volume of collaboration varies between the departments.

Departmental research portfolios reflect the dynamics in industry and society. Currently, two themes are strongly present in the agenda of every department, namely *sustainability* and *digitalisation*, well supporting KTH strategy. Digitalisation and sustainability are approached seriously on their own terms and not only as “pasted buzzwords” in the names of the research projects. As examples, in MMK sustainability means better energy efficiency with less pollution while IIP addresses circular manufacturing systems. For INDEK a cashless society is an extreme of digitalization, HPU approaches virtual production and LES develops an online math coach.

The departments have also assessed their *weaknesses*. The self-evaluations do not show much commonality. The panel brings up two joint weaknesses, namely *fragmentation* and some *overlaps* in the research portfolio. The departments are strongly recommended to revisit their list of research themes. The magnitude of fragmentation varies by department, but some need to reduce research themes considerably. An indicator of fragmentation is when the number of research themes exceeds the

number of professors. The academic community is eager to tackle new challenges. Abandoning old topics is harder. Thus, a systematic process is needed to manage the portfolio of research themes.

There are also some overlaps in research across the departments. In addition to “hard” research fields (science, technology) all the departments are inclined to tackle “softer” research fields (management, business, social sciences), where redundancies seem to pop up. For example, several departments indicate interests in business modelling. It is not resource efficient, if many departments create in-house capabilities in fields that are non-core among their peers in the academic community. Instead, networking and active cross-departmental collaborations are encouraged to be extended.

2. Feedback on the formulated visions and strategies

All five departments are oriented towards *sustainability* and *digitalization*. Both of them will drive changes in products and processes, including ways how they are designed, developed, sourced, produced, distributed, used and reused. Thereby sustainability and digitalisation have a strong impact on all five departments, but in different ways. Sustainability and digitalisation will also trigger disruptions in business ecosystems and business models. All the departments are well prepared for evolution and disruptions. The most striking change is seen in MMK, ramping down research of internal combustion engines due to major transitions and policy interventions in the markets.

Another common strategy is *growth*. Some of the departments aim to grow substantially. Only one department (MMK) has not a growth target, but MMK has just experienced 40% growth since 2012, mainly through successful increase in external funding. Even MMK aims to increase internal funding to reach a more stable structure of key faculty. However, in a contemporary university environment the strategy to grow is challenging. According to the recent statistics (OECD: Education at Glance 2020), in OECD countries investments in tertiary education have declined 7,1% in 2012-2017. In EU23 the decline was even higher (8,8%), but in Sweden slightly less (5,8%). So, the chance to grow with public funding opportunities is to be competitive in zero-sum games against other Swedish universities. In the Swedish university funding system, the primary KPIs for research performance are external funding and publications (UKÄ: Higher education in Sweden 2018, Report 2018:10). Every department under our review has improved research performance, so the facts support their growth strategy. Yet, it is unrealistic to expect major growth in internal KTH funding due to the overall funding limits. There is a call for focusing and collaboration, instead. Another route for growth can be built on external funding, which is one the key strengths of these five departments. Even though R&D funding in Sweden is one of the highest among all the countries (only Israel, South Korea, Japan and Switzerland peaked higher in R&D expenditure per GDP in 2015), there is no upper limit for R&D funding from non-public sources.

3. Ideas and recommendations for essential steps

The quality of research and the level of industrial collaboration are at a high level. Perhaps the best evidence is the 25th position of KTH in QS world university ranking (2021) in mechanical engineering, directly connected to the exceptionally high performance of MMK and IIP. This is a solid foundation to build for the future. Thus, there is no need for major renewal, but always room for improvement.

The departments are recommended to benchmark the strategy and operations development activities across the ITM school to learn and leverage best practices. For example, IIP is strong in strategic road mapping and using research KPIs. INDEK has a “raise high-low” procedure to systematically increase the lowest level of research output. HPU uses research quality improvement principles (publication quality, community engagement, industrial dissemination and PhD/postdoc processes). On top of all, LES is the leading unit on academic quality management in universities of technology in the Nordics. What seems to be missing is the systematic process for strategic positioning of research in the departments. This cannot be made in a vacuum, but together, supported by school management. Such a process needs to be performed “outside-in”, in collaboration with industry and policy makers. Such strategy workings serve also the purpose to manage the portfolio of research themes.

4. Potential links and synergies

RAE 2012 raised up several recommendations for development and most of them have been tackled with success. One of the observed challenges was a lack of cross departmental collaborations. Today, the situation is far better. The departments are well linked together, but it is hard to assess the synergies created through collaboration. A major ITM school initiative towards cross-departmental collaboration is the IRIS-project, launched in 2019 and triggered by KTH RAE 2012. IRIS consists of four interdisciplinary themes, each crossing the departments. In addition, IRIS intends to advance strategic collaboration, such as dialogue with KTH platforms (e.g. Industrial Transformation), dialogue with industrial partners and coordination between all ITM hosted centres (e.g. circular economy). Ramping up IRIS has met with difficulties reflected in changes of project management and setting up a formal project governance handbook. In spite of the problems, IRIS has exposed its potential for the departments, but a proper project plan with deliverables and milestones is still desperately needed. Moreover, measures to ensure cross-departmental collaboration must be strengthened. So far, IRIS has enabled several departments to learn to make use of post-docs.

ITM departments also have other traditions of collaboration. HPU is networked with IIP, INDEK and MMK. There is also a shared professorship between IIP and HPU. IIP makes benefit of LES in the engineering education activities of the department. However, there are also some symptoms of uncovered collaborative potential. Several departments work on similar research themes, such as business modelling. Researchers with similar research interests need to be brought together and work under one leadership, in line or in a matrix. This is a managerial challenge, where school and department management should work together.

5. Recommendations for strengthening the departments and their future potential

The departments are in different phases in their life cycle. IIP, INDEK and MMK are well established, with strong brands and traditions. HPU and LES are new as independent departments. Therefore, there is no single recipe for all the departments other than focusing on *fewer research areas* and aim towards global excellence. Systematic review of research portfolio is a managerial must. Recruitment decisions play a key role, when faculty members are entering or exiting. Other renewal measures are harder to be executed. Naturally, new professors are needed in new fields, but at least some retirements should be utilised as divestments. Currently, HPU suffers most from fragmentation. Merging HPU and IIP provides major potential to capitalize the inherent synergies, but the merger should be built on the strengths of the units involved to gain the benefits for Södertälje and Sweden.

Another joint challenge is related to *funding*, both capital and operating expenditure. IIP and MMK are capital intensive departments demanding modern research infrastructures with renewal needs in the tempo of technological advancements. To keep the competitiveness of ITM in the academic top of mechanical engineering requires a continuous flow of infrastructural investments. Regarding operating expenditure, the only notable source for growth is external funding, in which especially MMK exhibits mastery. External funding is often based on the networking talent of senior faculty. A generation shift has occurred and the new international professors require mentoring to build the Swedish connections.

6. Recommendations applicable to the whole of KTH

All five departments are concerned about the low level of basic KTH funding, high overhead costs and insufficient funds to upgrade research infrastructures. The panel strongly supports the departments, based on the high level of research performance and industrial impact.

The rules to allocate internal research funding through the schools to the departments are not transparent, even though the Swedish Ministry of Education and Research at least partly uses research performance related KPIs in allocating resources to the universities. Transparent, KPI-based internal

funding principles would increase the sense of fairness in the allocation of basic research funding. As behaviour follows measurements, this could also boost the quality and quantity of research results.

KTH is recommended to take infrastructural investments on the list of crucial topics to sustain the competitiveness of the university. University and school management should join forces in lobbying public and private stakeholders for fundraising for major infrastructural investments. It is not a matter of isolated campaigns, but a systematic, long term professional effort. KTH as whole could also consider innovative approaches to create and use research infrastructures, such as “industry as a laboratory”, joint infrastructures with industry, as well as modular and shared infrastructures. MMK and HPU have already taken steps towards such novel concepts.

KTH schools are oriented towards “hard” technologies and engineering. Two schools have a slightly broader charter, namely ITM and ABE. This is a strategic choice for KTH. Yet, the mainstream of the universities of technology operate with a broader palette of disciplines since the 1940’s triggered first by the predecessor of ASEE (American Society for Engineering Education). As the global/societal challenges are becoming increasingly complex, we recommend that KTH adopts a broad thematic focus on *Socio-Technical Systems* as a context for its engineering and technology excellence. This thematic focus should result in several and mutually beneficial initiatives that enhance research and collaboration, and a holistic approach to the SDGs. ITM school offers a potential hub for this focus given its convincing track record, with Södertälje (HPU) and LES as the most recent examples.

Part B: Report for each department

Department of Sustainable Production Development

Major findings

1. Strengths and weaknesses of the department concerned and recommendations for improvement

The department of Sustainable Production Development (HPU) is an academic startup, recruiting faculty from 2016-2017. The Södertälje location is a strength as such, based on the strong industrial presence in the region (i.e., Scania, AstraZeneca). The local industries have deep relations with academia, and there is a long tradition of educational collaboration since 1987 when KTH was established in Södertälje. The idea was to exploit this, creating a research community supporting industry transition to become more sustainable and to create academic knowledge of that area. So far, they have succeeded considering the time and human resources available. The relation with industry is unique and supported by regional and national funding schemes. The premises are excellent and provide unique opportunities for research and education. The faculty has a strong industrial background, and the panel appreciates in particular their enthusiasm. They demonstrate true engagement and really “live their topics”, engaging both with industry and their own staff.

The weaknesses are well recognised. There is a lack (and great potential) of contribution to the body of knowledge on Sustainable Production Development. Current research output is mostly based on conference publications with ambitions to increase journal publications. Relationships to other departments seem ad-hoc. The ratio of professors and PhD students is low, especially considering that professors have a heavy burden in management and administration. Research funding is heavily based on non-competitive public and industrial funding, which requires yearly results and outcomes.

The department is young, well organised, ambitious and courageous. However, only some of the important scientific areas of sustainable production can be covered with limited staff. The three divisions have names of connected to the professorships. These were fixed in the launch phase of the department and do not necessarily reflect its current and future mission. HPU is establishing an original positioning of “sustainability built in the manufacturing support functions” (e.g. maintenance, logistics, ramp-up and dependability). It also develops the notion of dependability (already present in the industry), potentially interesting for addressing issues around the sustainable cooperation in production operations. Hence, it would be more appropriate to include the term Operations in the department name, and this is well acknowledged in the department.

The announced merger with IIP is well acknowledged and appreciated in HPU. The merger brings along huge potential, as in the combined HPU & IIP, education and research of sustainable production will be in a much stronger position in KTH.

2. Relevant and forward-looking objectives

The long-term objective is to create a strong academic environment within Sustainable Production, initiating, co-producing and disseminating cutting edge knowledge to secure the future of the Swedish manufacturing industry, while contributing to environment and social development. The ambition is to become a National Node for Sustainable Production. The formulated long-term goals seem more oriented towards education. There may be a bias towards the local problems in the Södertälje area, and towards manufacturing and volume production (and less process industry or engineering to order).

The current research profile has two challenges related to the objective of becoming a National Node for Sustainable Production. One is that the current research focuses more on economic and environmental elements of sustainability than on social aspects. The other is the focus on Operations and Management, rather than a broad perspective on Production. The department is well aware of these biases - partly explained by its very recent creation and its efforts to be complementary with other

research themes in ITM. A clear strategy on how to fill the gaps mentioned is required. The IIP-HPU merger will provide opportunities to make the strategizing exercise in a broader context.

3. International community engagement

The department is active in creating contacts in the international community. HPU is young and many faculty members have industrial credibility and strong relations at national level. They create international engagement primarily in conferences, and research project related international collaboration is about to grow. The panel has observed clear ambitions for internationalisation, but operational plans are not described. We recommend that international partners, communities and journals should be more explicit in the plans (who, why and how). There is also an option to recruit senior faculty members with strong presence in journal publications, editorial work (etc.) to strengthen the department.

The panel notes that non-traditional naming and terminology applied in HPU might be a hindrance in the international perspective, unless claimed and constructed as relevant notions for the advancement of science, in which case it would become a strong scientific asset. The panel also understands that the naming was given to HPU at the outset.

4. Future potential of the department

The department works currently in three areas under the headline of sustainable Production Development: industrial dependability, production logistics, and production management. These fields are important but represent just a sample of elements of sustainable production development. Moreover, only some aspects of production logistics or production management belong under the umbrella of sustainable production.

The department should perform strategic analysis, identifying gaps and potential areas not covered today. It appears that building the sustainability of manufacturing support functions is actually at the core of the research program of the department - this might be stated more clearly - this appears as a promising way to address the issue of sustainability in production development. The panel considers that the name “Sustainable Production Operations and Development” would better fit the current profile of the department.

5. Recommendations

The department is advised to discover its identity by carrying out strategic positioning to align its academic work within the core area *sustainable production operations and development*. Gaps as well as unique strengths need to be identified and expressed by applying either common terminology or well-justified new terms. The department should clarify its contribution to sustainability (beyond listing the UN goals). Moreover, options for a more precise name for the department should be elaborated. HPU needs a systematic publishing culture internally with priority on journal publications with industry collaborators. HPU is advised to have a strong role in the merger with IIP with a vision beyond IIP in future partnering.

Specific issues

1. Research profile and quality

a. Central research questions and themes, and main research activities

HPU conducts research and education with the scope to improve sustainability of future manufacturing industries. The research activities are rooted in a close relationship between the development and operation of production and logistics systems, and conducted within the context of digitalization and sustainability (including circular economy).

- Industrial dependability with the following focus areas:
 - Advanced machinery and their subsystems operational capability and performance.
 - Industrial analytics for prognostics and health management of manufacturing assets. Combination of data-driven with knowledge-based for a hybrid physics-based analytics approaches to e.g., understand root-cause failures and predict errors before they occur.
 - Data-driven solutions for decision-making and increased manufacturing performance.
- Production logistics with the following focus areas:
 - Analytical applications based on a digital representation of the production logistic system. Applications for visualization, evaluation, management and development.
 - Circularity for sustainable production. Production logistic flows that create resource efficiency. Development and improvement tools.
 - Production logistics visibility. Transparency upstream and downstream, real-time information and multi-criteria models for operation and development.
- Production management with the following focus areas:
 - Production management and strategy, focusing on different aspects of lean production like corporate lean management and lean & digitalization, production localization and change management.
 - Industrialization & scale up, dealing with the process of industrializing a new product, going from prototype to volume production and including established companies as well as start-ups.
 - Resource efficient operations, where the focus is on create stable processes by efficient and digital deviation handling, as well as on research questions on the environmental part of sustainability including circular economy.

The research also involves KTH's Lean Centre and Södertälje Science Park.

For the panel all these areas are vital and representative for the overarching area and are covered by researchers and PhD candidates. In the perspective of Sustainable Production and digitalisation there are elements not covered by the current profile. Also, the research is more directed towards contributions to sustainability than sustainability research (theory, methods and models) as such.

In production management the focus is more on strategy and lean applications, while digital systems and digital transformation are covered less.

On direct question the department placed itself in Production Operation Management, if only one term was allowed. The panel also remarks that the term Dependability is very interesting, but not yet established in international academia. The application area of HPU in terms of general industrial sectors are not precisely defined beyond the general term of manufacturing industries.

b. Contributions to the advancement of state of the art within the research fields of the department

The department is still in its building phase. It has been able to develop knowledge in smaller segments of application areas and is publishing in highly relevant conferences and journals. The volume of the journal publications is growing, but still at an early phase. The maturity of the department is still about to develop towards a high contribution research unit. There is potential!

c. Quality and quantity of contributions to the body of scientific knowledge, engagement in national and international research collaboration within academia and its outcomes

The publications are primarily in the form of conference papers, moving towards journals. The collaboration on research within the international community is about to grow.

Recommendation:

- International partners, communities and journals should be more focused in plans (who, why and how)
- The team should also consider taking some editorial responsibilities to help diffuse its scientific productions (guest editor of special issues, participation to editorial boards and later to become editors, editors-in-chief, ...).

d. Follow-up from previous evaluations

Not applicable in this evaluation, as the department was established after KTH RAE2012.

2. Viability and research environment

a. Internal and external funding; current status and strategies for the future

HPU is living on governmental, municipal and industrial funding, topped by some amount of KTH internal funding. The background was the harsh situation in the region. This funding largely is non-competitive, which means that there is no direct rivalry from other KTH units or universities. Similar funding is secured for several years ahead. However, such a funding model does not necessarily last forever and cannot form a long-term foundation for any academic unit. Even in the current situation the costs of premises are high and students have not yet sufficiently discovered the educational programs offered. Therefore, the funding situation is already tricky. The department has been alerted to identify the related issue and the associated risks and the actions to reach critical mass in research and education are under way.

There are strong drivers to expand education in the Södertälje area, covering both continuous and degree education. However, the assumption that the needs and thereby funding opportunities for research are proportional to education can be challenged because the underlying drivers are different.

b. Academic culture

The panel was pleased to observe that even though the department is new and quite recently set up, partly from scratch, the governance structures have already been established and functioning. The strong commitment of the department management and the enthusiasm and dedication of the

personnel could be sensed in the interviews. There is a joint, meaningful mission where everyone wants to contribute.

An area which was not surveyed was connections between research and education of HPU and KTH Södertälje site more generally. We suggest that the department would make a further self-assessment how research driven the education of HPU actually is.

c. Current faculty situation and composition of the research team(s)

HPU organisation is currently very lean, in particular regarding resources for management and research supervision (3 full and 3 associate professors). As one of the professorships is joint with IIP, and with other commitments among both the full and associate professors, the actual total capacity is in the ballpark of 4 FTE professors. We recommend that the department takes these limits into consideration in the research roadmap to reach excellence in research results and impact.

d. Recruitment strategies

There is a clear and well-articulated plan towards the optimal faculty structure for each research group: 1+ full professors, 2 associate professors, 1 assistant professor, plus other staff; 12-15 per department. Having such a plan as a guideline for the development of the organisation is a strong merit. However, due to the scale effects in research work such a set-up could be considered more a minimum size for a productive research group rather than optimal. Regarding the state-of-the-art in HPU, there still is a way to go to reach the minimum viable level of a productive research group.

HPU can be considered a start-up as an academic unit. It has been able to attract talented people, perhaps due to the sustainability mission of the department. There is still work to be accomplished to increase the attractiveness of the department from the perspective of international top talents, regarding both potential faculty members and students. However, the institution is still young and it takes time to build and communicate a new brand and its value proposition. HPU management is well aware of the challenges related to recruitment and works consistently with the handicaps.

e. Infrastructure and facilities

HPU leverages the facilities of an industrial partner (Scania) in the Södertälje Science Park. Such a beneficial use of joint research infrastructures with industry is warmly welcomed also elsewhere in KTH with Södertälje as a great benchmark. HPU also takes advantage of the research facilities of Mälardalen University, which is another valuable benchmark to be followed.

Own infrastructures are in the building phase although the facilities for production logistics are already operable. The specific needs for future infrastructures remain a bit obscure in the self-evaluation report. However, we do not consider this gap a handicap at the moment, as we are strongly advising HPU to discover its identity after the successful ramp-up phase, in the new situation, where the future oriented plan to join the forces of HPU and IIP is needed anyhow.

3. Strategies and organisation

a. Goals for development 5–10 years ahead

HPU intends to pursue its growth, from the building phase to a scale-up, intending to become a national Node for Sustainable Production, with three identified targets: build proper research environment capable to address critical issues in sustainable production, develop lifelong learning education to support industry change and strengthen industry collaborations, e.g. through internships. One challenge will be to keep a balance between the necessity to cover a large number of topics for education purposes while focusing research on smart positioned topics to reach critical mass.

b. Congruence with university-level goals

HPU is well aligned with university level objectives Leading education, Leading Research and Leading Collaborations. In particular, HPU contributes to leading education in many ways, from preparatory education to lifelong learning. Regarding the seven “elements” or prioritised areas, HPU is particularly contributing to digitalisation, sustainable development, internationalization (new international master, networks with key countries South Korea and Germany), and gender equality (active gender-aware management).

c. Leadership structure and collegial structure

In this new department, managerial structures have been carefully established. Management team and the department head are the key roles. The organization also integrates the relationship with KTH Södertälje. Besides the three research groups there is also the “Lean Centre” to be run. This adds managerial work and complexity. Moreover, in academic work education is dominating in volume over research and the personnel is divided accordingly. There are obvious risks for the management in such a situation as research is generally valued over education in university organisations.

d. Strategies for achieving high quality

Strategies for achieving high quality are well formulated and built on four key principles: 1) publication policy, 2) community engagement including conference participation, 3) industry-academia dissemination and 4) structured PhD and postdoc processes. The department has set up processes to support the shift from conference papers to journal papers, based on pulse meetings and KPIs. However, there might be challenges to implement the QA-strategy, as the senior faculty is so limited.

4. Interaction between research and teaching**a. Interaction between research and teaching at all three levels (B.Sc., M.Sc., Ph.D.) of education**

The tradition of KTH Södertälje site since 1987 was built on undergraduate and preparatory education. In 2014 the profile was upgraded to cover master level education. Regarding doctoral education, the two PhD programs run in Södertälje are related to IIP and INDEK. However, there are strong intentions to create a HPU specific doctoral program with preferences towards HPU research topics.

It is perhaps a bit too immature to evaluate the effectiveness of the interaction between research and teaching in HPU, as the track record of the department specific research activities cover only a couple of years and the department specific doctoral education is in its launch phase. Instead, it is more sensible to comment on the plans on how to integrate research and education. The panel notices that the overall plans and intended actions sound welcome and reasonable. HPU was able to develop clear assets to best articulate research and teaching:

a) relevant content: teaching is based on research results obtained on relevant industrial questions. Research themes are well-positioned in collaboration with industrial partners that are also potential employers, and (some of) the research outcomes are then taught in seminars and lectures;

b) geographic location: research and teaching facilities close to the workplaces and capability of attracting more diverse groups of students than KTH traditionally;

c) multiple channels: HPU is developing a broad range of education services to articulate research and teaching at several levels, preparatory education, lifelong learning and degree education (BSc, MSc, and PhD). HPU makes strong use of course projects, internships and industrial PhD theses.

d) expertise: many researchers are also professors, able to make direct links between research results (not only their own) and teaching materials - not only by delivering courses but also by writing textbooks and textbook chapters.

The panel advises HPU to reconsider the idea to limit the doctoral activities only to HPU specific topics. As the scale of Södertälje operations is relatively small, more scale could be achieved through cross departmental, transdisciplinary research and education activities, perhaps even beyond IIP and INDEK departments that have been active in Södertälje, so far.

5. Impact and engagement in society

a. Relevance, scale, and impact of the department's current engagement with society and industry

Industry-academia networking is the key mission of the whole KTH Södertälje campus. HPU is living this mission. Thus, the industrial and social impact is the rationality and key strength of the department. Strong focus towards continuous learning serves the short term societal mission and the research, building on the needs for industrial transformation towards sustainability contribute to the long term industrial and societal needs. As the department has been in the ramp-up phase, the focus so far has been in the proximity of the KTH Södertälje campus. As an academic unit is not viable by focusing its efforts merely in the close neighbourhood, and we advise to expand the span towards the whole Sweden also including international partnering.

b. Research dissemination beyond academia

The basic setup of HPU is favourable for research dissemination. However, as the networking is so close, there is a risk to incline towards short term interests of industry through consultancy flavoured research on the cost of bypassing opportunities for new breakthroughs. Artificial respiration to lengthen the lifespan of dying businesses through incremental innovations is another risk to consume scarce research resources.

Fortunately, also SMEs and startups are on the radar of HPU. We advise HPU to give sufficient room for collaborating with SMEs and startups even though their human and financing resources to support collaboration are scarce. The rewards, in turn, could be astronomic.

c. Relation to sustainability and the United Nations' Sustainable Development Goals (SDGs)

HPU is well aligned with UN SDGs focusing on: 9) Industry, innovation and infrastructure, 12) responsible consumption & production and 13) climate change. These topics are actually the core of HPU academic activities. The focus on social aspects of sustainability still has potential at HPU.

d. Plans and structure for increased impact

HPU has a passionate approach to enhance sustainable production. Thereby the plans are perhaps at the aggregate level leaving room for more detailed actions and structure.

6. Recommendations for strengthening the department and its future potential

As pointed out in this report there are several actions recommended for strengthening the department and its future potential. Of utmost importance is to take full advantage of the merger with IIP, seeing this as an opportunity to expand and strengthen sustainable production operations and development in the joint HPU & IIP department, ITM school and KTH as whole, because IIP has an excellent knowledge of actual sustainable production operations.

There is a need for HPU to (re-)discover its identity, regarding scientific themes, industrial relations and impact. KTH Södertälje has strong potential of serving ITM and KTH as the key node for sustainable production. There are also needs to focus and identify the gaps in the current profile. HPU is encouraged to not only support but also drive sustainable production based on solid scientific argumentation. As industry - academia collaboration adds value in both directions, HPU could leverage and conceptualize the production transformation excellence that Scania created in Södertälje in the turmoil of the global financial crisis in 2008.

To systematically prioritize journal publications is also fundamental in the future process. There are also needs to expand resources, streamline processes and be even more targeted in selecting journals to publish. Related to this is a recommended effort in taking up editorial duties, as well as making use of relations to create more international co-authorships.

7. Final remarks

The panel learnt on August 16, 2021 that HPU will be merged with IIP. The panel welcomes such a strong decision to reorganise KTH Södertälje activities. The new setup sorts out many of the overlaps across the five departments, as the current HPU parallels some 80% with IIP (dependable production and production logistics) and 20% INDEK (production management).

The problem to rediscover the identity of HPU will be converted into the problem to rediscover the identity of KTH Södertälje outlet. So, the problem as such remains a complex problem.

The panel hopes that merging HPU and IIP will lead to cross-fertilisation of the research themes. From HPU perspective, it could be an opportunity to improve its positioning (e.g., on sustainability built in manufacturing support functions) and benefitting from IIP experiences on regular road-mapping exercises. The future HPU-IIP department needs to be organised for two site operations with minimum overlaps but still forged as a strong unit.

In addition to degree education and research, KTH Södertälje campus can be tuned for a major hub of KTH lifelong learning as the neighbour is filled with workforce in need of (re)education

In addition to incumbent companies, the Södertälje area has potential for technology start-ups and scale-ups in various fields. Accordingly, doors should be open for research of all the KTH fields of expertise and supported by hands-on technology-based entrepreneurship education, provided hopefully by INDEK experts.

Department of Industrial Economics and Management

Major findings

1. Strengths and weaknesses of the department

The starting point in INDEK research is the relevance of research for individuals, companies and society. Such an approach is definitely welcome, but also demanding as the intended utility of research is twofold: epistemic for the academic community and pragmatic for the industrial community. Of course, “there is nothing more practical than a good theory” (attributed to Kurt Lewin) - here this means that scientific elaboration and industrial relevance can be fruitfully combined and this capacity to find efficient synergies is critical for INDEK.

There is evidence that INDEK's ambitious intention to combine scientific contribution and socio-economic impact runs on a successful trajectory as the number of WoS publications has grown since RAE 2012, and there are plenty of reported impact cases. One of the strengths of INDEK is its growing orientation towards sustainability and digitalization. Here the strategic parallels of KTH, ITM and INDEK are more than obvious.

Organizationally, INDEK is today much stronger than 2012 in its international orientation reflected in international faculty and publication intensity. This trend can be expected to continue, even though the international doctoral education (EDIM) was ramped down. One of the instruments to continue this trend is related to the ITM school wide IRIS initiative, which enables INDEK to benefit from post-doc positions and to develop systematic practices to manage this resource in a fruitful way.

Regarding the weaknesses of INDEK, the self-assessment exposes a clear understanding of the challenges the department is facing: “INDEK's faculty is spread over a broad number of sub-disciplines, leading to a situation of un-critical mass”. The number of research topics is in the same ballpark as the number of professors, which implies that a critical mass for voluminous research excellence can be reached only in a few areas. The panel strongly recommends INDEK to commit firm actions towards a more focused research theme portfolio. This does not necessarily mean to delete research topics but rather to clarify how the topics can support each other to contribute to more generic research issues, often in a dynamic way, where mature topics support the emergence of ‘exploratory’ topics launched to become the powerful research themes of the INDEK of the future. For the management this might be an opportunity to showcase research themes differently.

2. Relevant and forward-looking objectives

INDEK aims to build its future on core goals (1) growth, (2) platform / hub for entrepreneurship, (3) KTH platform for economics research and (4) external communication. The approach is to grow through large(r) projects to reach a critical mass of research activities in the core areas, of which entrepreneurship and digitalization are explicitly mentioned. The development of solid external ties, based on regular meetings and communication is needed to regularly attract research funding from foundations or corporations, to enable long term research programs, less sensitive to uncertainties of competitive external funding. Such a strategic plan is relevant and consistent. Selecting entrepreneurship, digitalisation and economics are forward looking choices, as there is potential to grow and have impact in these thematic fields. The panel underlines that these topics have the potential to organize positive synergies between scientific contribution and industrial relevance. The panel also notes that there is a strong global as well as local competition on these topics and suggests that INDEK has a more unique and original approach to these topics, for instance taking advantage of INDEK unique position in engineering and technology management. The panel notes that INDEK relies very positively on its ‘historical heritage’ (Taylorian tradition, socio-technical approaches, Scandinavian school of management, ...), and suggests that this historical heritage be leveraged for supporting future research programs.

3. International community engagement

Since the early 2010'ies INDEK has been systematically active to increase international recruitment, international publications and international collaboration in research and PhD education. This multiple front approach in internationalisation has been successful. Currently, the faculty is international, and the international publication record is clearly at a higher level than in the days of RAE 2012. The department has launched multiple means to advance international research collaboration, such as EDIM, SCAIEM and SDA. The panel suggests that INDEK might also consider other dimensions of international engagements, that help to show how a research school plays an influential role in international academic institutions. These dimensions could be participation to editing boards (as board member, as editor, as editor in chief, as adviser...), capacity to build and grow new academic communities on new breakthrough topics, contribution to international debates, etc.

4. Future potential of the department

INDEK is strongly committed to fulfil its goal to enhance its position among the leading academic players in its fields. The research approach of INDEK is driven by relevance for individuals, industries and society. The selected thematic, in particular entrepreneurship, digitalization, economics and sustainability are those that possess huge potential for beneficial impact on society.

5. Recommendations

INDEK is encouraged to continue its positive development towards an internationally recognized research institution in its fields. INDEK's transition from a national, education focused university unit towards an internationally recognized research and educational institution is impressive. However, in the higher echelons the competitive landscape gets tougher and even keeping the position is a challenge as such. Competition covers all key aspects: talent (faculty and students), financing (national and international), top journal publication space and access to corporations with relevant research challenges in the business environment. Competition is driven by quality. Quality, in turn, is related to scale achievable through smart positioning or rich resources. Perhaps the latter is not a realistic option.

Specific issues

1. Research profile and quality

a. Central research questions and themes, and main research activities

INDEK presents the central research questions in a layered model: macro, meso and micro. At macro level the research questions deal with the economics of innovations and growth. Methodologically the macro level is approached through economic theories. The meso level deals with a broad range of themes, of which sectoral and technological transformation, innovations, eco-systems, sustainability, energy management, regional development, and technology diffusion are mentioned as examples. Micro level deals with managerial and leadership questions, such as human factors, operations and supply chain management, project management, organizational leadership, technology, innovation and R&D management, gender studies and change, health care management, IT management and entrepreneurial processes. The panel notices that this presentation with three research questions might actually be challenged since there might be management needs and socio-technical issues at all levels - as shown by contemporary transitions.

Raising the central research questions at a meta level seems to be a handy way to expose the diversity of the research activities of INDEK in a compact-looking scheme. The detailed fields of the research exposed in the self-assessment report are highly relevant as such and amenable for both contributions in the scientific body of knowledge and in the practical utility in the industrial community. However, a note on sharper focusing is applicable also here, to ensure sufficient depth and breadth of research activities.

b. Contributions to the advancement of state of the art within the research fields of the department

INDEK is brief in the self-assessment report to share the contributions to the advancement of the state of art. The primary means are indicated as research, training, speeches and debate articles. Multiple research fields are mentioned elsewhere in the report, e.g. cashless society, innovation policy, Covid-19, equality, gender, re-skilling to programmers, sustainable transition and systemic innovation. The panel assumes that INDEK is perhaps modest to estimate its contributions. All the more so that, when looking at the 9 selected papers, the panel was really impressed by the uniqueness of the results (high quality review papers, rich empirical material, and strong theoretical propositions). Elsewhere in the self-assessment report, e.g., the following other items are mentioned: virtual reality, software development academy (SDA), business models for electric road systems, high capacity transports, safety management in airlines, sustainable aviation, and carbon dioxide removal.

Perhaps the most impactful instrument is INDEK's research related educational programme in Industrial Economics and Management, which is one of the most popular engineering programs in Sweden, producing a growing pool of highly influential alumni with the capabilities to transform and sustain the Swedish economy. INDEK also made EDIM a huge success, with a record number of theses. The panel encourages to capitalise on these theses, transforming these in publications and future research grant applications.

c. Quality and quantity of contributions to the body of scientific knowledge, engagement in national and international research collaboration within academia and its outcomes

The trend in the number of peer reviewed publications at INDEK has been growing (DiVA database) since RAE 2012. Naturally, there are annual random variations. There is also a slight increase in the impact factors of WoS publications. In any case INDEK has improved performance in publishing. Rather than writing conference papers the concentration is towards peer reviewed, impactful journals. The approach has been successful and INDEK has received bonus funding based on publication performance as the best performance improvement at ITM school. Further progress might be achieved by focussing on publication impact (impact factor, awards, etc.) rather than publication quantity per se.

During the recent years INDEK has been active to launch several national and international research activities. This, together with the internationalisation of the staff will provide a huge future potential to increase the quality and quantity of publications and social impact. A good example of this within INDEK is the highlighted (nr. 8) Research Policy article on “Academic engagement and commercialisation ...”, where Anders Broström is one of the authors together with colleagues from 12 other top universities and research institutions. Currently (July 1, 2021) the number of citations of the particular article is 2038! Congratulations! The panel is also impressed by the originality of some of the research results and the richness of the empirical material produced by INDEK for the research community. There is always a risk in a research community that the “publish or perish” rule pushes towards works that build on existing material (well-known data) and address narrowly defined research field - the panel would like to underline that INDEK publications precisely provide the research community with rich empirical material and open new research fields, hence contributing to a living, dynamic collective research.

d. Follow-up from previous evaluations

INDEK has taken the feedback given in RAE 2012 seriously. A multitude of improvement actions has been carried out. Regarding the recommendation to perform an intermediary research evaluation, INDEK has prioritized monitoring and evaluation of research with special emphasis on the continuous and steady flow of articles in high quality journals. As a consequence, KTH has reached through INDEK status in some of the global university rankings in management and economics. This is a good start bearing in mind that the competition in these particular rankings is against all full portfolio business schools. INDEK has also reorganized its research activities to improve publication performance and the effectiveness of research. Two new research platforms, sustainability and digital transformation, have been launched, indicating the response to RAE 2012 suggestion to address phenomenon/challenge-driven research.

RAE 2012 also gave recommendations to advance research towards services with the transformation of manufacturing companies from pure product business towards integrated products, services and solutions. The response of INDEK is currently shown as research in business models, digitalization, sustainability, utilities, health care and transport.

A proposal to enhance cross departmental and KTH wide collaboration, e.g., in entrepreneurship and sustainability was also expressed in RAE 2012 evaluation. The ITM school wide IRIS project and the SSES (Swedish School of Entrepreneurship) platform are excellent examples, how response to RAE 2012 feedback has materialized in value-adding, long term activities.

2. Viability and research environment

a. Internal and external funding; current status and strategies for the future

The revenue of INDEK is about 100 MSEK, out of which 30-40% is dedicated to research. The majority of funding is consumed in education due to the extensive education provided across KTH. Most of the research funding is basic KTH funding. In the 2010'ies, a major share of external funding was based on the EDIM programme. Ramping down EDIM resulted in a gap in research financing, not yet compensated by other income. Current research funding is 31 MSEK, i.e. 1/3 less than the peak in 2012. This is not a catastrophe, but research funding is one of the major strategic points INDEK should address. During the panel interviews, INDEK mentioned that a fair amount of external funding has been won since the self-assessment report delivery. Research project applications have been launched and INDEK has a clear strategy to apply for bigger funding mobilizing multiple competences. INDEK will try to make sure that funded projects can follow on each other, with better tractability of research results. INDEK has also initiated fundraising activities for new professorships.

b. Academic culture

During the 2010'ies EDIM was a key enabler towards internationalization. The faculty became more international. In the post-EDIM phase the voluminous pool of international PhD students is gone, but the new IRIS postdoc initiative provides a natural continuation to enhance high quality research with the resources more mature to carry out independent research. Obviously, the volume of IRIS does not correspond to EDIM, so additional measures to move forward are also needed. INDEK aims to make a clear separation between education and research and increase the efficiency of education. The panel emphasizes that high quality, effective education is the trademark and primary impact engine of INDEK. Educational technologies have taken major breakthroughs, so there is potential for educational development, including efficiency improvements. However, we do not encourage INDEK or any other department to approach educational efficiency on the cost of educational quality. INDEK has also committed actions to vitalise academic debate on several platforms ranging from faculty assembly to various seminar platforms. INDEK has played a central role in SCAIEM (Scandinavian Academy of Industrial Engineering and Management). Recently, SCAIEM conferences were extended to cover research interests. SCAIEM has grown to a vehicle to foster togetherness and identity of IEM in the Nordics. A natural step forward would be to enhance the European dimension.

c. Current faculty situation and composition of the research team(s)

INDEK faculty covers some 45 persons plus doctoral students. The number of professors is 28, with associate professors dominating in numbers. The department is composed of three divisions: (1) Management & Technology, (2) Sustainability, Industrial Dynamics & Entrepreneurship and (3) Accounting, Finance, Economics and Organization. The division structure is fairly recent. Though the number of divisions is small, the number of disciplinary subjects needed just to name the three divisions is nine. This can be explained by the necessity to cover many areas for teaching purposes, however, there is a need to combine diversity and a more focused agenda.

d. Recruitment strategies

INDEK has been successful in international recruitment. Research merits are prioritised. Gender balance is also emphasized. INDEK has no post-doc tradition, but the IRIS program enables possibilities to make use of post-docs.

e. Infrastructure and facilities

Industrial Economics is not a discipline demanding heavy infrastructures beyond space and computing facilities. Contemporary AI-flavoured research approaches together with INDEK's strong involvement in industry level research set demands to access large data bases. In spite of the low investments, adequate data resources are absolutely necessary prerequisites for successful research in these areas.

3. Strategies and organisation**a. Goals for development 5–10 years ahead**

The primary intention of INDEK is to grow, with priorities in entrepreneurship and digitalisation. A networked operational model (platform/hub) seems to be preferred, at least in the domains of entrepreneurship and economics. However, the strategic plan to grow and orchestrate platforms is not without risk. The panel suggests INDEK to complement the strategic plan with proper risk management. What if there will be essential delays for financing large projects? What if the KTH platform for economics research would be located outside ITM?

Regarding entrepreneurship INDEK is in a collaborative and competitive relationship with five other Stockholm area universities. The 20 year old platform SSES (Swedish School of Entrepreneurship) is

branded, assumingly not by chance, close to Stockholm School of Economics (SSE). Currently, SSE is primarily oriented towards educating entrepreneurs, and it would be a major effort to extend the operating model of SSE to incorporate academic research on entrepreneurship. In this situation INDEK could elaborate other approaches to optimize research results in entrepreneurship.

The panel suggests that INDEK takes full advantage of its historical heritage in engineering to make a difference in fields (entrepreneurship and digitalisation) that are highly competitive.

b. Congruence with university-level goals

KTH aims to be a leader in research, education and collaboration. INDEK is positioned excellently in education and well in research and collaboration. In most of the universities of technology industrial engineering is positioned at the department level. At KTH industrial engineering and management is a school level discipline, which indicates the exceptionally strong level of integration at university and school level. It shows the importance of management for engineering research and education, as well as the uniqueness brought by engineering to research in management. In practice, INDEK as the department serves as a role model with high intensity collaboration across ITM and the rest of KTH. However, these collaborations are more related to teaching than research. Collaborations on research topics should be encouraged (ranging from platforms and centres to departments).

The other university level elements (visibility, openness, digitality, sustainability, globality and equality) are also well presented in INDEK. Even though INDEK has a relatively good gender balance, the department keeps on working to improve it.

c. Leadership structure and collegial structure

INDEK has a management team (MT), professors' assembly, teachers' assembly and supervisors' assembly. The supervisors' assembly is about to be converted into a research assembly. Additionally, the Swedish labour law sets a demand to organize regular employee meetings (APT). Department development meetings are organized for communication purposes. For a less than 50 persons organization the number of leadership positions seem to consume a fair share of scarce resources. The managerial structure beyond MT is primarily "product" oriented, with one team for education and other for research. APT is compulsory. The rest of the organisation stems from the culture to ensure that everyone gets onboard. The department could consider if some roles or organs could be combined, keeping in mind that research administration precisely might require that the roles are distributed on everyone, so that a) everyone is aware of the collective management issues; b) people holding managerial responsibilities keep enough time for their own research/education; c) there is a sense of collective engagement, in a research organisation where there are always strong centrifugal forces.

d. Strategies for achieving high quality

INDEK has a "raise high-low" approach to enhance research quality in order to systematically increase the lowest level of research output. In practice the target is to aim for publications in high ranked journals (Web of Science). For each faculty member the output should be >1.0 Pfrac WoS during a 3-year period. This procedure indicates a tangible approach to enhance quality in research.

The panel suggests enriching the criteria for output evaluation, for instance by taking into account the research awards, that show that research results are recognized as significant and original by the research community.

4. Interaction between research and teaching

a. Interaction between research and teaching at all three levels (B.Sc., M.Sc., Ph.D.) of education

Interaction between research and undergraduate teaching has a long and strong tradition at INDEK. In addition to conducting high volume educational activities for both the dedicated few students specialising in industrial engineering and the large volumes of students needing some engineering management knowledge to complement their specialisation, INDEK faculty has been active in developing courses, educational methods and writing textbooks and thereby leveraging research results captured locally at INDEK and globally among the IEM community. The majority of courses at master level are taught by faculty and include elements of inhouse research.

Interaction between research and PhD teaching at INDEK is currently limited. Recently, INDEK has budgeted financial resources in order to launch new PhD courses.

KTH, ITM and INDEK could perhaps also consider other trajectories to develop doctoral education. One possibility could be to concentrate strongly on the PhD projects and thereby reduce the share of courses as part of the PhD degree requirements. As the contemporary trend in BSc and MSc education is to extend the breadth of knowledge, a PhD student could have the right to deepen understanding maximally in the particular field of research. Consequently, such a rearrangement to invest in the depth of knowledge would enable an increase in the quality of research, in particular if the journal article format of PhD theses would be preferred. Still a high-quality kappa (in a thesis on paper) also requires a real capacity to handle more than a narrow research area - hence a balance needs to be found.

5. Impact and engagement in society

a. Relevance, scale, and impact of the department's current engagement with society and industry

The nature of industrial economics and management as a discipline underlines relevance in respect to companies, industries and society. The current research portfolio, covering a multitude of items, such as digital transformation, sustainable transformation, equality and equal treatment in society and organisations, cashless society, future work, knowledge workers, business models and systemic innovations, expose that INDEK researchers are addressing serious industry and society related challenges.

Even though there are mixed experiences of shared industry-academic positions and industrial PhDs at INDEK, it would be sensible to estimate the conditions for success / failure and develop preparations and procedures to increase the potential to improve.

As the strategy of INDEK is to grow and the research fields of INDEK are closely connected to companies, industries and society, the growth scenario is hard to be realised without deep collaboration with industrially oriented partners. Attractiveness improvement requires systematic attention in research themes, marketing and communications, as well as a solid portfolio of potential partners, not only at medium management level but also at top-executive level in companies or agencies.

b. Research dissemination beyond academia

INDEK applies multiple channels to disseminate research results for different target groups. The faculty includes several persons capable of delivering relevant news and media coverage in their areas of expertise. In addition to disseminating results to large publicity, the faculty members are welcome and willing to share their research results and views among the dedicated professional communities. The knowledge created in the fields of INDEK is also highly relevant for vocational and executive education.

INDEK has not reported to arrange “studia generalia” or alike open events nor get-togethers for the impactful and large INDEK alumni as means for dissemination and research / educational promotion.

c. Relation to sustainability and the United Nations’ Sustainable Development Goals (SDGs)

INDEK is strongly committed to UN sustainable development goals (SDGs) and has launched activities to support most of the 17 UN SDGs. Regarding sustainability the focus is in circular economy, sustainable transition and management, economics of sustainable energy systems and green economics. Sustainability oriented research papers cover currently about 20% of the research volume measured in journal articles at INDEK, which can be considered as a great result. Moreover, recent faculty recruitments support the strategic direction towards sustainability. INDEK is also a central partner in the MSc Program in Energy and Environmental Sciences.

d. Plans and structure for increased impact

The list of INDEK impact cases attached in the self-evaluation report is convincing. The best news is that the themes of the impact cases emanate from the urgent industrial and societal problems. However, the panel is surprised that KTH Executive School as the natural channel for impact distribution is currently not applicable in ITM in general and INDEK in particular, due to avocation restrictions.

6. Recommendations for strengthening the department and its future potential

Overall, INDEK has exposed strong positive development during the last decade. The recommendations of RAE 2012 have been followed to improve strategy, structure, practices and performance. INDEK has also possessed dynamic capabilities to benefit from unforeseen opportunities, for example in the internationalisation of faculty and activities.

However, in RAE 2012 INDEK was advised to enhance its research results by focusing the research activities in fewer topics. Even though INDEK faculty in 2021 is much larger than in 2012, it does not justify that the number of research themes have obviously grown proportionally. Thus, INDEK is strongly advised to organize its research activities in a few core programs where projects can build on each other. This could strengthen INDEK “thin red line” (as INDEK management described the department) by strategically combining powerful focused research and agile explorations. Strategy (particularly in research!) is the art of making explicit clear shared orientation for collective, well-connected, still varied explorations, that support each other.

The panel strongly supports most of the development ideas mentioned on the self-evaluation report. In particular, we underline the need to receive long-term research projects in the core areas of INDEK. Relevance based research can be carried out only in close and deep collaboration with industries.

Doubling the number of faculty by 2030 is one approach to reach critical mass in research activities. As such the approach includes multiple uncertainties and risks, INDEK is advised to create a thorough action plan to achieve the ambitious target. Moreover, it would be sensible to have multiple scenarios regarding both the target setting (e.g. 20% / 50% / 100% increase in the number of faculty) and the means to achieve the target (e.g. internal funding / external funding / hybrid funding). It is noteworthy that the current, history-based resourcing model of KTH does not support radical, discrete changes in departmental resources through internal resourcing, although INDEK has a case for performance based additional funding. Naturally, an alternative to organic growth through increased resourcing is to achieve scale through scope, which alternative is also worth deep elaboration.

7. Final remarks

The panel would have appreciated receiving a decent project plan for the IRIS initiative. Additionally, the available financial data is also somewhat inadequate to make well-argued conclusions regarding the infrastructure and personal structures. However, these comments are not related to INDEK or any other department, but rather on the higher levels of organisation.

Department of Learning

Major findings

1. Strengths and weaknesses of the department

LES is a relatively new department that has been formed out of a restructure of divisions of the School of Education and Communication in 2017. This restructure primarily focused on strengthening the research mission and to establish a critical mass of research active staff in five identified areas of potential excellence. The research approach of LES can be characterised as applied and action-based, in line with a pan-university service role of LES in terms of professional development of staff and digital technology. As some staff originally had an administrative focus, substantial and successful efforts have been made to develop a research culture by a range of pro-active strategies (see below). There is emerging evidence that the increased focus on research of the department has led to sustained research output, and increased research excellence, as the number of publications and WoS in particular has grown. Furthermore, the two impact cases of Maths Coach Online and Conceive-Design-Implement-Operate (CDIO) highlight substantial impact and reach beyond KTH. Moreover, recently published works and reflection on the transforming and transformative role of education in society stands out. A particular strength of LES is the sustained emphasis on enabling and developing education as a whole, including teachers, students, pupils of all kinds, school, university, continued education. Another strength is the orientation towards digital education, sustainable future, and global competence in line with the overall strategy of KTH.

This is the first research assessment exercise for LES. Organisationally, LES is today much stronger than in 2017 in both its research focus and overall strategy. This trend can be expected to continue. LES has a respected reputation as a thought leader in education in KTH, and in several of its core research fields. This status can be leveraged in research consortia for external funding. The internal financing has been fairly strong, with increased recognition that LES staff are research-active academics in their own right. This has enabled growth and specialisation and it is foreseeable that the situation will continue due to the digitalisation strategy of KTH. Relative to other technical universities, LES appears as original and unique and many other universities might be jealous to have a similar department.

Regarding weaknesses, the self-assessment shows a clear understanding of the challenges the department is facing: “Activities in the Department are not fully aligned, or strongly linked to clear goals and strategies for development, dissemination and impact of research.” LES has other key assignments, in particular education, ITM and KTH wide other services and collaboration with primary and secondary level education. This variety of assignments makes the corporate identity of LES and its personnel somewhat tricky, as well as its external brand recognition. Furthermore, the relatively limited volume of external funding and high teaching and system development workloads (e.g., VLE) limit the opportunities for growth in research, although recent grant success in 2020/21 points to early success. As the number of senior faculty is relatively small, the resources needed to enable growth as a research unit are somewhat limited. The panel strongly recommends LES to continue to commit firm actions towards a focused research theme portfolio. For the management this is a tough choice. Every recruitment has a strategic importance, and creative ways need to be found to combine innovation in teaching across KTH with applied research, whenever opportunities arise.

2. Relevant and forward-looking objectives

LES has an ambitious and forward-oriented vision built around three core goals: 1) expanding the research academic staff to match the number of teaching staff; 2) acquiring external research grants; 3) recruiting high-profile early and mid-career faculty. LES further aims to establish KTH as a thought leader in higher education research and development, a nationally recognised centre of excellence in STEM outreach through the House of Science, and research focused on development of engineering education. LES intends to grow in research. At present the main yardstick set for LES is the educational

capacity, but such a yardstick can be challenged! The volume of educational activities is due to the substantial pan-university and pan-school educational services (e.g., language, communication and pedagogical education), parts of which are compulsory to the students and/or staff, requiring large educational resources. A similar causality cannot be set for LES research, although the internal funding could be used as a leverage for matched funding when applying for external (e.g., EU) funding.

3. International community engagement

There is evidence of international community engagement in the respective divisions and impact cases. In some of the research areas networking and research collaboration level is exceptionally high, including project-based joint activities. In other areas these are based upon individual networks and editorships of various international journals. In particular CDIO has been used across hundreds of programme leaders worldwide. Maths Coach Online is, for example, used in the UK for K-12 students around the Aston University (Birmingham) area. Given the strong policy focus on Swedish/Nordic contexts and teaching expertise LES is extremely well embedded in the Nordic higher education and policy context. We would encourage LES to further extend and diversify their internationalisation strategy beyond the Nordic region and include this in their recruitment strategy.

4. Future potential of the department

LES and its earlier incarnations have been in a key role to enhance and distribute CDIO and other innovative methods in engineering education. This has perhaps boosted self-confidence to foster further advances in some of the research fields of LES. With the increased digitalisation of higher education and needs for both professionalisation of teachers/academics and global competence LES is well placed to position it as both a strong central KTH pan-university unit and a leading research unit. LES can build on the further strengthened reputation following the substantial essential service provision during the pandemic in terms of digitalisation and excellence in digital pedagogy.

5. Recommendations

The LES mission is to advance education in science and technology through education, research and societal impact. Historically, educational assignments dominated the portfolio. The challenge of LES is to ensure coherence of the staff where a majority (around 80) are educators and a minority, but a growing number, are research-active (around 18). At KTH research is often valued over education, and a two-tier organizational culture might be created. Supported by ITM and KTH, LES management needs strategy and procedures to cope, mitigate and manage the risks of inequality feelings.

LES works on multiple frontiers: schools (primary, secondary), KTH education, engineering education and higher education in general. In addition, LES addresses thematic matters (i.e., equality, sustainability, societal change) in many of the frontiers of education. LES has been impactful in its workings. However, the panel advises LES to reconsider the size of the research portfolio to match the size of the senior faculty and its research (supervision) capacity. Perhaps less is more, or alternatively synergies between research topics need to be explored to establish a critical mass of internal/external expertise and excellence across all core research topics.

LES aims to expand its research through increased internal and external funding, and as an alternative through internal transformation, i.e., replacing retiring lecturers by new assistant professors. Regarding the cost, such organisational transformation might be ingenious. Yet, the panel assumes that the duties of retiring lecturers will remain. Replacing a lecturer by a research focused professor is an option only in exceptional cases! Therefore, we recommend LES to explore other alternatives as well.

Specific issues

1. Research profile and quality

a. Central research questions and themes, and main research activities

LES presents the central research questions mostly in a unit by unit manner. Research areas correspond to some extent with the organisational structure of LES. At present there are limited questions on a macro/national/international level. The meso level deals with a broad range of themes, including (in alphabetical order) engineering education, policy development, internationalisation, STEM education curriculum, systems thinking, and universities as organisations. Micro level deals with digital technology, emergence of new response strategies to change, professionalisation, technological and pedagogical competencies of educators.

The detailed fields of the research exposed in the self-assessment report are highly relevant, and commonly found in similar higher education research institutions in Europe, as such and amenable for both contributions in the scientific body of knowledge and in the practical utility for KTH and the wider educational sector. The group of digital learning is surprisingly small taking into consideration that Covid-19 pandemic has propelled digital learning into the most urgent challenge of learning technologies. Similarly, the group of global competence seems relatively small, in particular in terms of research outputs. While four new associate professors (mathematics education, higher education development and gender mainstreaming, sustainability and engineering education, higher education research and development) have recently been recruited, these seem mainly in existing research topics that already have substantial traction (i.e., HESOS, LEEaP). A note on sharper focusing is applicable also here, to ensure sufficient depth and breadth of research activities.

b. Contributions to the advancement of state of the art within the research fields of the department

LES research has gained high international reputation and recognition at least in HEOS, digital learning and LEEaP. In digital learning the achievements concern the learning of mathematics. Nonetheless, LES is relatively brief in the self-assessment report to share the contributions to the advancement of the state of art. The primary means are indicated as philosophy of engineering education, digital learning, and STEM education curriculum. Multiple research fields are mentioned elsewhere in the report, e.g. professionalisation, technological and pedagogical competences, and policy development. The panel assumes that LES is perhaps modest to estimate its contributions. Perhaps the most impactful instruments are LES research related educational programme in Maths Coach Online and CDIO, which both have large uptake and reach.

At the same time, with the rapid advancements in engineering education and educational research LES could consider investing (or “piggybacking” on investments made by other KTH units) in state-of-the-art (education) research approaches and methods, such as artificial intelligence, augmented reality, educational data mining, learning sciences, learning analytics, neurosciences, and multi-modal learning labs, as well as contributing to large-scale policy initiatives to sustainability and global competence. Similarly, there are substantial opportunities to keep on co-creating and evaluating innovative approaches in KTH together with students and teachers. Finally, it might be useful to be more explicit in terms of who LES sees as its benchmark institution, and how it aims to compare itself with the wider sector.

c. Quality and quantity of contributions to the body of scientific knowledge, engagement in national and international research collaboration within academia and its outcomes

The trend in the number of fractionalised publications and conference papers at LES has been growing (DiVA database) since 2012 from 3 to 10 in 2019. During the interview a detailed breakdown of recent research output showed a substantial increase in publication output, in particular also in WoS. At the same time, some research outputs do not fit within current WoS (e.g., teacher innovation papers

published in Swedish language) but do provide local relevance. In any case, LES has improved their performance in publishing. However, the starting point was very modest and the current level of articles (approximately 10 per annum) is still modest for a university organization of approximately 18 researchers and around 80 staff who also conduct practitioner-led research and scholarship.

In general, the quality of contributions across LES is high. For example, the CDIO work is highly cited in Google Scholar and well adopted in the global sector, which is excellent. Furthermore, the recent conceptualisation paper of Hrastinski on blended learning is promising to be highly cited. Nonetheless, several of the papers mentioned of high impact work are mainly short conceptual, descriptive, or systematic review papers. While these papers are interesting and relevant, the list of exemplar papers seem to miss studies that are ground-breaking large scale empirical, evidence-based and/or lab-based that substantially advance the field of educational science and engineering education in particular. There seems to be an epistemological disparity between the strong engineering, innovation and technology focus of KTH and LES. With a strengthening of ties within ITM and KTH in general of innovative practice and conducting research in their labs, substantial opportunities for high-quality educational research are ripe to be picked.

d. Follow-up from previous evaluations

This is the first time that the activities of LES are evaluated in the RAE process. Therefore, there is no earlier yardstick to compare the current situation to an earlier status.

2. Viability and research environment

a. Internal and external funding; current status and strategies for the future

The revenue of LES is about 40 MSEK, which is mostly from internal KTH funding to cover the large pan-university activities and services. There is a substantial increase in unit funding, from 10 MSEK in 2013 to 40 MSEK in 2020. There are some signs of early success in increased external funding from the Swedish Research Council.

b. Academic culture

There is a strong inclusive and open culture with a vibrant and dynamic research community. A vast range of inclusive activities are organised for interdisciplinary research and engagement. Department-wide seminars are arranged as well as more specific cluster seminars, and the KTH teaching and learning conference. The research culture is further supported by the appointment of a Head of Research in 2021 to prioritise external funding applications and publication strategies. Nonetheless, the organizational structure (research clusters vs. divisions) is somewhat complicated, but hopefully the communicative and respecting mode of operations would compensate for this handicap.

c. Current faculty situation and composition of the research team(s)

LES faculty covers some 85 persons plus 15 (internal/external) doctoral students. The number of professors is 3, with lecturers and research engineers dominating in numbers. This is a reflection of the extensive teaching and service workloads of LES. The department consists of three divisions and one centre: 1) Learning in STEM, LiSTEM; 2) Digital Learning; 3) Language and Communication; and the House of Science (centre). This division structure is fairly recent. Though the number of divisions is small, there are five disciplinary subjects (HEOS—Higher Education Organization Studies, Technology and Science Education, Digital Learning, LEEaP – Leading Engineering Education and Progress, Global Competence). There is some confusion/inconsistencies in terms of (lack of) the branding on the website/social media (e.g., Twitter, Researchgate), as well as in the self-evaluation report. The LES organisation is dominated by lecturers, which reflects the role of LES to provide language education, pedagogical education and professional services for KTH. The research teams are all fairly balanced

regarding senior and junior faculty members and recently recruited staff, although substantial further emphasis in (international) recruitment might be needed in digital education and global competence to effectively support the KTH strategy.

d. Recruitment strategies

LES aims to recruit high-calibre scholars on an international level, in particular in global competence, digital learning technologies, and higher education research. Four associate professors have recently been recruited. The IRIS program may enable possibilities to make use of additional post-docs. LES seems to have recognised that replacing a lecturer with a heavy teaching load by a research oriented associate professor does not work out! However, one wonders whether a more high-level strategic recruitment of a senior professor with extensive international networks and external funding would speed up and stabilise the growth ambitions.

e. Infrastructure and facilities

LES is not a discipline demanding heavy infrastructures beyond space and computing facilities. At the same time, with advances in learning sciences (e.g., AI, eye-tracking, learning analytics, learning design, multi-modal studies) we would encourage a more ambitious (co-/joined) investment in state-of-the-art facilities to tap into evidence-based lab studies and learning science studies. Here, cross-departmental infrastructure use may be explored, such as for example with MMK and IIP on (virtual) prototyping facilities.

3. Strategies and organisation

a. Goals for development 5–10 years ahead

LES aims to build its future on the core goals of 1) expanding the number of research academic staff to match the number of teaching staff; 2) acquisition of external research grants; 3) recruitment of high-profile early and mid-career academic staff. The primary intention of LES is to grow, with priorities in digital technology and global competence. The goal of LES is to grow and recruit 5-10 new faculty members for research per annum during the next five years. Such massive growth is planned to be financed through external funding acquisition. The panel is doubtful whether the ambitious plan to grow in faculty (5-10 per annum) is realistic unless external grant acquisition is rapidly upscaled, and thereby the panel recommends LES to develop clear targets that focus on key research domains and related objectives.

b. Congruence with university-level goals

LES is extremely well placed to align itself with KTH goals. As the department plays a major role in training skilled educators and support the efforts towards digitalisation it fits well with “A leading KTH”. Furthermore, the global competence research and practice helps in equipping and nurturing engineers with essential 21st century skills. We strongly encourage LES to consider ‘prototyping’ education by joining up with innovations in other Departments (e.g., Machine Design and their prototyping lab) and study educational innovation, new technologies and new modes forms of education together with MMK and other units at KTH. With a continued effort in research on these topics LES can help to further strengthen KTH to be a leader in research, education, and collaboration. The other university level elements (visibility, openness, digitality, sustainability, globality and equality) are also well presented in LES.

c. Leadership structure and collegial structure

LES is managed by a Head of Department, supported by a Department Board consisting of the heads of the four divisions, the director of studies, and the departmental controller. The department board

meets bi-weekly. Furthermore, each division holds regular staff meetings, and division heads have 2-3 meetings with each member of staff. A particular mention is the two general retreats to discuss the strategic development of research and teaching to develop a joined vision across the department, and a sense of collective ownership of the mission. Leadership and collegial structures are managed professionally at LES.

d. Strategies for achieving high quality

LES has a systematic model for enhanced research impact. Normally the yearly research performance reports are discussed at the Department Board and as part of the annual staff retreat. The newly appointed Head of Research will facilitate the cycle of goal-setting “to respond systematically towards enhanced excellence and more extensive research and societal impact”, although it is unclear how these valuable aims are translated into concrete targets, and how these are supported. LES has, among other competences, capability to build and apply quality assurance systems for higher educational institutions. LES has also capability to walk the talk, which implies that the quality assurance procedures for LES research are properly set up.

4. Interaction between research and teaching

a. Interaction between research and teaching at all three levels (B.Sc., M.Sc., Ph.D.) of education

In principle, this is the core strength of LES given its focus and research interest. LES is a department that is dedicated to education, in particular science and technology. LES creates a direct link between research and education in its own academic activities, with HEOS group at the edge. In digital learning the research results are directly applied across KTH, in particular during the pandemic.

There is strong interaction across all three levels of B.Sc., M.Sc. and Ph.D. between teacher education and skills development initiatives in KTH and research within LES, as well as engineering students studying language, communication and intercultural competence. In particular the Technology and Learning programme is an attractive offer. While historically teacher training programmes were taught by non-research active staff, this is gradually changing into research-informed teaching. A particular opportunity for further synergies with industry is that Master theses at KTH are often written in collaboration with an external partner. An excellent example of how LES is supporting KTH in the interaction in research and teaching is the MOOC development, which is also informing regular courses at all three levels. As argued, the “fourth” academic level of competence development of KTH staff is a particular merit of LES to help to make sustainable change in education at KTH.

While the strong focus on teachers/staff by LES is historically reasonable and understandable, the panel would encourage LES to consider more clearly embedding the student voice in design, (co)creation, and innovation in KTH. With a changing student population, it is important to help KTH staff how to build more inclusive, equitable and diverse learning experiences for students. For example, there are opportunities in linking learning data and learning dispositions of students at KTH with providing effective learning paths and learning designs using AI and learning analytics approaches. LES could be a leading driving force for empowering student-centred innovative design at KTH.

We also encourage LES to capitalise on their overview as a pan-university unit by further strengthening their measurements of reach and impact within and across KTH. For example, capturing existing and emerging publication networks across KTH using social network analyses will help to illustrate how actively LES staff are engaging with innovation and research with other KTH colleagues and external collaborators, and how these are changing over time. Systematically capturing the short- and long-term impacts of professional development activities, and learning from these activities of what has worked (and what not), will also help to continue to make an effective university-wide investment case in LES.

5. Impact and engagement in society

a. Relevance, scale, and impact of the department's current engagement with society and industry
LES research is applied extensively in educational development and assessment in the Swedish primary, secondary and higher education system. Key public stakeholders are mentioned in the self-assessment report to collaborate with LES. Research projects include work on science epistemology and gender awareness in science, which insights are applied in teacher education programs for preschool and primary teachers.

In the self-evaluation report industrial partners are mentioned as users of KTH MOOCs. The Panel suggests LES to elaborate possibilities for industrial collaboration also in other areas of digital learning. Augmented and mixed reality are examples of high potential value for complex learning challenges in industry.

b. Research dissemination beyond academia

The report mentions two examples, the annual Researchers' Night and MOOCs. The House of Science centre leads the Researchers' night which is a great opportunity for the Swedish public to engage with science. The second initiative of MOOCs shows a global impact beyond academia, whereby LES has supported 17 unique MOOCs at KTH with 122K enrolments across 150 different countries. Two specific professional certificate programs are provided by LES together with industry. It would be useful to explore how these programs impact local and wider society, and how these translate to new enrolments, industry collaborations, etc.

c. Relation to sustainability and the United Nations' Sustainable Development Goals (SDGs)

LES is strongly committed to UN sustainable development goals (SDGs) and has launched a range of activities to support most of the 17 UN SDGs. In particular, the research at LES supports goal #4 (quality education), # 5 (gender equality), #9 (industry, innovation and infrastructure), #10 (reduced inequalities), #16 (peace, justice and strong institutions) and #17 (partnership) drawing on strong networks for international collaboration and contributions to the Unite! University project. In conclusion, LES is strongly committed to promote UN SDG goals.

d. Plans and structure for increased impact

LES uses some social media and academic publication to increase the impact of LES research. STEM is mentioned as an area where impact is aimed to be increased, too. However, the plan to increase research impact does not sound highly impactful. It would be useful for LES to set up a departmental profile in ResearchGate to increase visibility and track usage, citations, and impact data over time. Furthermore, a dedicated communication plan and departmental Twitter account would help to raise future impact. The Government National Initiative (ULF) could be a great vehicle to engage young people with STEM education and practical school research, and the panel is pleased that this project has been extended till 2024.

6. Recommendations for strengthening the department and its future potential

Overall, LES has exposed strong positive development since 2012. Regarding internal funding KTH management (e.g. the President) has promoted LES research (e.g. mathematics education, equality, sustainability). Excellent relationship to KTH management and continued measurement of short- and long-term impact on educational innovation is a matter of survival for LES, also in the future. Actions to raise external funding need to be strengthened. A systematic approach is needed.

Substantial traction of LES has been achieved within ITM and KTH since 2017, which has also been confirmed by the other units. With the pan-university mission of LES to provide both thought leadership and excellence in engineering education, the panel encourages LES to develop a clear strategy making sure that substantial traction remains and is deepened within the research themes and across KTH. There are natural and strong synergies between educational innovation and educational research. Given the strategic importance and themes in KTH strategy that LES can support and champion (e.g., digital education, global competence) the momentum is now to move beyond building ad-hoc, personal 1-to-1 networks across KTH towards a more integrated, ambitious, and transformative strategy. Several routes could be used, including prototyping with KTH units, co-creating innovative designs with KTH staff, setting up satellite LES staff /connectors in each Faculty, recruiting and embedding innovation champions from each Faculty into LES network and vice-versa, creating joined innovation funds for truly ground-breaking educational innovations in KTH (i.e., seed funding), etc.

With a fair wind in the sails of LES due to the pandemic and a wide recognition of the need for innovation and digital and student-centred education in KTH, there is a window of opportunity to build and nurture the next generation of researchers in KTH and LES who can co-construct, design and evaluate the next socio-technical society. It is essential to prioritise key research topics that have both current critical mass and future potential. The recruitment strategies should focus on addressing any gaps in key and/or emerging research topics that have relatively low coverage, or whose areas are expected to grow (e.g., AI, digital education, dynamic evolution of human-human interaction, global competence, learning sciences). Continued professional development and opportunities for personal growth in parallel are paramount to help all LES and KTH staff in general to reach their full potential.

7. Final remarks

The panel would have appreciated receiving a decent project plan for the future goals. Additionally, the available financial and publication data in the panel 7 report are also somewhat inadequate to make well-argued conclusions regarding effectiveness of the divisions, infrastructure and personal structures. However, these comments are not related to LES or any other department, but rather on the higher levels of organisation. We appreciate the detailed publication figures that were provided during the panel interview by LES, which addressed most of the gaps on available financial and publication data.

Department of Production Engineering

Major findings

1. Strengths and weaknesses of the department

The development of the Department of Production Engineering is described very clearly. A convincing description of a restructuring and redirecting towards the future process based on recommendations of the last RAE process was achieved. The department has chosen three main areas of working: Digital Smart Production, Manufacturing and Metrology Systems and Sustainable Production. This proves deep knowledge of the production engineering environment and a clear concept of how research can provide society and industry with results that will maintain a sustainable balance. The driving force for this renovation appears to be the XPRES initiative that has supported researchers investigating low TRL areas that have been the root of IIP success. It also recognizes its own strength in the positioning of its research activities (besides XPRES e.g. SFO,CE@KTH) and in international academic networking (e.g. CIRP). Assessing the strength and excellence of IIP it is very important to understand that their work relates extremely well to pressing questions within industry. IIP recognizes clearly that the mass production and mass customization paradigms have to be challenged. New ways for value creation need to be explored. Building on EPS (Evolvable Production System), reusability, factory-in-the box, hence a “scale-independent” production system is central to the work of IIP and seen by the department as a distinguished strength. It clearly is in line with KTH goals of sustainability and digitalisation.

IIP’s effective collaboration with industry, includes research areas of high potential like big data and circular economy and gives proof to the fact that it established procedures for monitoring and possibly redirecting research efforts for the better of surrounding society. It is embedded in a strong international network. This new structure achieved a lean organization. It provides connecting points to other departments. It is very important to understand that subsequent cooperation and interdisciplinary work is the way into the future to solve the complexity of the problems ahead. To do so is the real strength of IIP. Its awareness of its strong track record in impactful research results is acknowledged.

At the same time the report reflects clearly on weaknesses. Even though these weaknesses are recognized they seem to be seen a bit beyond the department’s control. As far as the budgeting is concerned this is accepted. Still there can be internal measures to counteract funding by project proposal strategies which in fact the department is very successful in. The gender misfit is to be compensated with new PhD and postdoc positions. There is a language handicap in BSc education because international staff does not teach in Swedish and for the same reason a lack of participation in the Swedish Production. Some of these issues need to be dealt with at KTH level and can only partially be compensated by the department. Topic gaps due to missing experts in the staff is a tenacious issue for all departments as public budgets are not unlimited. What clearly is an issue for dealing with such questions is the necessity for transparent rules and mechanisms for budgeting at school and KTH level. We strongly recommend to put in place transparent administrative procedures and an internal transparent budget discussion as ingredients for effectively supporting research excellence.

The report mentions the IRIS initiative. It is a budget as well as an interdisciplinary working opportunity. After some discussions regarding this topic, the panel has reached the conclusion that IRIS is not developed as far as it should have been in response to the last RAE process. It has the potential to foster interdisciplinary cooperation between departments and even schools. To make this really work we recommend to first derive jointly a roadmap (e.g. for the next five years) above departmental interests. This could catch the enthusiasm of young researchers and lead to a successful blueprint for interdisciplinary problem solving.

Summary: The goals of IIP are very relevant and forward oriented. In the context of the school, they have a structured starting point for interdisciplinary work and offer and invite cooperation. In view of the discussions the panel had with all departments, we strongly recommend using these connections points between departments consciously to push even more for research and teaching excellence.

2. Relevant and forward-looking objectives

The department displays a clear list of relevant and forward-looking objectives. It is of no use to repeat this list but it is very important to note that the management board of this institute obviously has understood the main boundary conditions which are in need of answers for the future. It is participating / initiating work on circular economy, on additive manufacturing, on how to organize production sustainably, on how to shift the focus from mass production as well as from mass-customization, to new ways of value creation, on the role of sharing etc. In its work the department breaks this down very well to what this means at research level.

These objectives clearly are relevant and forward-looking. Still, improving excellence also means to concentrate on essentials. The panel therefore asks not only IIP but also all other departments to double check on overlaps and solve underlying issues. All work related to sustainable production should address all three components of sustainability.

3. International community engagement

The self-evaluation reports a strong engagement in the international research community. The list of international partners is impressive. Derived from own cooperation with Fraunhofer IPA we confirm the validity of the claims for international links in the report by external sources. The European projects IIP has been involved in show the excellent footprint this institute has left and is leaving in the European research environment. IIP Department has been extremely active in international recruitment and research collaboration.

4. Future potential of the department

Production engineering besides maybe agriculture is the place in society which is still dedicated to actually create value, to provide jobs based on real income and to provide mechanisms for supporting the standard of living in our societies. The future potential of the institute is directly connected to this. It is huge. The focus of its work is in line with this societal necessity.

5. Recommendations

Excellence of Research is besides scientific achievement depending on relevance of topics, trustful cooperation among the partners, transparent decision processes, enough budget for the task ahead, administrative processes in place which allow to clarify disagreement based on mutual esteem of each other and a continuous road mapping which supervises research results and directions. The panel recognizes that the department has laid out processes and connecting points which can and should be used, to jointly move forward within the frame of the school (e.g. XPRES). This work of IIP should be strengthened and boosted. The faculty is international and strongly networked with other leading institutions in the field. International research collaboration is exceptionally high and so is industrial collaboration. This is to be kept at this level.

The faculty consists of a fairly small number of professors (4 full, 3 associate and 2 assistant). It would be advantageous to concentrate on the number of topics.

Specific issues

1. Research profile and quality

a. Central research questions and themes, and main research activities

The department aligns its central research questions and themes very well. This strategic approach is supported by the structure of the department. If the name of the IIP department “production engineering” is seen as the spearhead of its goal the topics evolve logically and future oriented. The original starting point was production. The ongoing work made it necessary to extend the technological approach. Technologies like additive manufacturing play an important role. At the same time international endeavour to promote production including respective technologies resulted in the recognition that technology alone cannot solve the complex problems of the future. One needs to include business models, circular economy and the impetus on sustainability. Digitization is a key element but taken on its own it is not a good lever. IIP presents a convincing and coherent approach to this research work. It is important to see that the work starts to look beyond Industrie 4.0 because it is recognized that there will have to be a shift away from the mass production paradigm. Industrie 4.0 is what the name tells, an industrial undertaken. It is not Academia 4.0. The time for delivering specific research results into Industrie 4.0 has passed because the huge efforts in enterprises of big players like Siemens show that at an institute level there will be not the tools and devices this industry has developed for the purpose by now. For the sake of excellence, it needs to be highlighted that the department has started to move beyond this paradigm.

There are two more aspects that need to be mentioned. The work of the department starts to include big data analysis. Without a deep understanding of statistical interdependencies and respective analytical methods future engineers are not prepared for their job in industry.

The other aspect concerns the organization of the research topics. This organization can be compared to a bonding model in chemistry. The organization offers bonding options for external cooperation within and without KTH - which can be used advantageously only if the organization has the willingness to push for this opportunity, a clear knowledge of today’s industry, a capacity to anticipate future external expectations, and to dynamically evolve the research portfolio. The department shows an excellent ability to contribute and to cooperate at the level of central research topics. XPRES focuses on the innovative sustainable business models and the consequent development of cloud manufacturing. The circular production topic as well as the cooperation with local SMS are very good indicators of this excellence.

While it is clear that the IIP department has a thorough and well thought portfolio of research questions and themes, we observe that this breath-taking list of themes needs to be seen in the light of senior faculty resources. We recommend sharper focus!

b. Contributions to the advancement of state of the art within the research fields of the department

This question goes beyond the self-perception of the department. To assess this point, one has to consider how external players perceive the work and the achievement of the department. There are two very positive indications. As mentioned earlier there are a number of external partners who are willing to finance PhD students independently. This would not happen if the outside parties were not convinced that the work performed advances clearly beyond the state of the art and has a very good chance of being applicable in the world outside academia. The other very positive aspect is the number of EU projects that have been acquired in a relatively short time. Proposing projects in the frame of EC project calls has a winning chance of roughly 10 %. So, chances are very low that one wins projects. For the department this case is different: comparatively many projects plus project results were recognized by EC evaluation as outstanding (CAPP-4-SMEs and SYMBIOC-TIC rated success stories by the EC). This is only possible if the department can build on an excellent international network, provides

excellent and high-quality input for the research, develops research topics to the next level within the international research community and (most important) has an internal organization to achieve excellent results. As this is peer reviewed at many different stages this excellence is out of question. IIP researchers have scored multiple awards.

c. Quality and quantity of contributions to the body of scientific knowledge, engagement in national and international research collaboration within academia and its outcomes

The last two points clearly are interlinked with this subtopic. Collaboration and engagement at national and international level has been positively answered in the preceding sections. The reorganization of the department has put it into a very good position to develop scientific topics in the realm of production technology beyond the status of today and provide answers for pressing problems of tomorrow. The work at editorial level as well as the published papers, the currency of academia, are presented in the self-evaluation and support this argument strongly. Prof. Lihui Wang is one of the most frequently cited researchers at KTH. In the department's video very distinguished results of his work were demonstrated. This is just one more indicator that there is a powerful team of junior researchers underlying the work in all the department's units.

d. Follow-up from previous evaluations

The report discusses 10 issues raised by the previous RAE process. The department created a new more rational form of organization. The results are very promising and successful. Even for attracting more female master students progress was achieved. Overall it is observed that the department took the follow-up very seriously, started its reactions to the requested changes well before the next RAE process was to come and proved clear progress. The department did an excellent job with this reorganization.

2. Viability and research environment

a. Internal and external funding; current status and strategies for the future

The funds acquired for research are given but the reader is left with the question as to what has to be covered by this money. The mechanisms for budget allocation at KTH seem to be historically tricky and for the future we strongly recommend to strive for more transparency in this process.

The report shows that the funding situation has been stable since RAE2012. It expresses an incline of external funding (Vinnova, Vetenskapsrådet, STINT, Horizon 2020), but the financial reporting (Figure IIP-6) does not confirm it. The horizon of public funding is roughly five years. On this basis, planning is very difficult and any academic institution is left alone with this dilemma.

b. Academic culture

IIP has experienced a generation shift and the age distribution is somewhat balanced. Gender balance is still an issue, but there is light in the tunnel with MSc and PhD student recruitments.

c. Current faculty situation and composition of the research team(s)

The report gives a staff of 54 members of the department in 2020. 10% of the staff is supporting research work and infrastructure permanently. There are 11 professors, 4 of them full professors. How the teaching load is redistributed in the new organization is well described.

We are not given any student numbers nor an absolute reference to the teaching capacity required but if one takes the three subdivisions of the department then an equal distribution of staff would leave 18 per subdivision. Taken at this high level It seems that this is a rather good ratio and certainly is in favour of high-quality work. But no clear description of the obligations of the staff is given.

d. Recruitment strategies

Currently there are openings for new positions. The necessity of which are established objectively based on the research topic. The department follows the clear recruitment rules of KTH. IIP has representatives in the KTH Admissions Board.

The IIP Academic Development Plan follows the natural evolution of senior faculty and tries to reinforce personnel for potential new topics. This Plan is revised annually and includes assumptions for growth. Among the panel there are concerns about what happens when seniors retire. Will there be a lot of energy waste until the replacement is settled?

e. Infrastructure and facilities

The self-evaluation report lists high quality equipment that is at the disposal of the department. It also indicates that the Additive Manufacturing team is building on its own initiative a large-scale plastic 3D printer. The equipment is not limited to department use only. Sharing is organized. In general, it can be judged that the department is very well equipped for ongoing and future research.

At the same time there are concerns about options to necessary expansion in response to the demand of high-quality research. This concern is shared by the evaluators. It is strongly recommended to implement a transparent administrative procedure that enables investments on infrastructure along the IIP strategy for the horizon until 2030. The panel discussed in the interviews with different departments, options for sharing infrastructure even with industry. Despite obvious difficulties this might be a way into the future, and it could be tested especially at the Södertälje campus.

3. Strategies and organisation**a. Goals for development 5–10 years ahead**

Biannual IIP road mapping exercises are used to analyse, identify and renew the research areas and pinpoint future technologies. The discussion in the interview confirmed this to be a very good and solid approach. This process includes many people in the department and thus achieves belief into the prospects. Success is obvious. Given the proven ability of Prof. Onori to work on roadmaps (cf. Assembly Net Road Map for precision assembly industry) the descriptions are very credible.

b. Congruence with university-level goals

The upper most goals at university level are given as interdisciplinarity and digitization. The department works in reference to these high-level requirements. The department argues convincingly that interdisciplinarity and digitization as such are nice but not sufficient if taken as stand alone. It needs to be knit into the context of the overall work. Production engineering with its many aspects is an ideal application.

c. Leadership structure and collegial structure

This again has been covered at other portions of this report. In restructuring the department clear leadership has been proven. It is also important to understand that this was done in the spirit of strengthening the collegial structure. There is good leadership at the top of the department which allowed for very strong leaders in the units.

d. Strategies for achieving high quality

A vital contribution is that the IIP research areas are no longer confined to the individual units. The road mapping efforts have produced the above depicted IIP Research Areas as multi-disciplinary directions in which all units of the department collaborate. It also offers options for interdisciplinary

work beyond the department boundaries. IIP has a strong strategic position. Its identity as a centre for hardware production technology needs to be understood. Extrapolation into the future is not possible at the stage of this evaluation as KTH announced an important change, the merging of HPU and IIP.

4. Interaction between research and teaching

a. Interaction between research and teaching at all three levels (B.Sc., M.Sc., Ph.D.) of education

IIP reports a complete change of its approach in this domain. While RAE 2012, observed that IIP was organized according to a traditional KTH approach that separated teachers and researchers. Their teaching was based on old material which by now has been replaced because the organization for teachers has changed. Older staff, permanent teachers have retired by now and the teaching load is shared by faculty, senior researchers, some PhD students that follow a teaching ratio of about 75% teaching and 25 % for research. In the general average this method achieves a sharing of cutting-edge knowledge in the different fields, a renewal of teaching material and a tuning to insisting on competences versus just knowledge delivery. Therefore, IIP is now well in line with the KTH policy that each faculty should pursue at least 15 credit equivalents of pedagogical education. Pedagogical support is offered and accepted by the teaching staff. This is an ongoing process.

The impression given by the report is that the Bachelor as well as the Master theses are often an integral part of national projects contribution and are, in most cases, defined together with industrial R&D colleagues. This has the positive effect of strengthening IIP ties to industry, and to apply leading edge research. The third cycle courses at IIP include an explicit element of research where they are required to publish or scientifically communicate the output of their activity throughout the course. The related topics are well aligned to production technology: assembly technology, digital factories, circular manufacturing systems, additive manufacturing, and cloud manufacturing.

The new research field in manufacturing engineering education is a logical consequence of IIP activities and it is no surprise that IIP is very active in this area. We encourage to fine tune this with LES.

5. Impact and engagement in society

a. Relevance, scale, and impact of the department's current engagement with society and industry

Production engineering assisted by solid engineering design is / should be one important centre of society's interest because this is one of the few places in which real value is created. This is where we need new answers as some of our paradigms do not really work any longer. Agriculture is another place of this quality. Modern agriculture, the food factory, has a clear link to production engineering principles. Services do not qualify as we will not be able to live on "holding the door for each other".

IIP is in a good starting position for this necessary exchange with surrounding society. All IIP department units are active in engaging the society in general and the industry in particular to discuss and advance the beneficial use of research results. IIP is an active partner in multiple EU projects that aim towards common good. XPRES is a clear engagement to share scientific knowledge with society. CORONA will force us to seek new ways of living at many levels. Supply chains do not work the way they used to. Impetus for local production is needed. Going for the cheapest solution in a faraway country is already now proven to be a wrong decision. The topics of IIP in terms of relevance, scale and impetus for society's need are positioned in this field. This is very relevant.

b. Research dissemination beyond academia

As a consequence of subtopic a) research dissemination beyond academia should be strengthened. E.g. Unions in Sweden have responsible persons for research. There is a recognized Swedish strength: cooperation between employers, the unions and public administration to seek ways to strengthen the economic position and the situation of the Swedish workers. Especially for IIP it would be important to link to and cooperate with such organizations. This goes beyond publishing papers, but the need of the day is to get scientific answers for society's pressing problems.

c. Relation to sustainability and the United Nations' Sustainable Development Goals (SDGs)

Is documented in the self-evaluation.

d. Plans and structure for increased impact

The report lists KPIs which are going to be the scale for structuring increased impact. KPIs are always a delicate description. They often go beyond what possibly can be achieved. But the underlying effort to do better than living on the "principle of hope" clearly is recognized and valued. It is not the absolute value of a KPI but the intention it describes that matters. The department provides insight into an ongoing strategy process behind. The plan is perceived as a realistic and promising way forward.

The current research impact agenda of IIP is exceptionally strong.

6. Recommendations for strengthening the department and its future potential

Overall, IIP has shown a strong positive development during the last decade. The recommendations of RAE 2012 have been used to improve strategy, structure, practices and performance. IIP possesses dynamic capabilities to benefit from unforeseen opportunities, for example in the internationalization of faculty and activities.

The strategic way into the future is not simply some nice excellent academic field of work. Any successful change of any organization to adapt to future excellence had three ingredients: putting the organization (the way of internal and external cooperation) on a testbed and remodel it, double check the area of work (or product) and adapt it to future customers' needs and seriously checking the administrative backbone (does it support the needs of the work area, what are the costs of the overhead in comparison to - in this case - research and education spending). To review these aspects and take appropriate action is our strongest recommendation. It needs to involve the school and KTH administration,

In the case of IIP this has clear implications. Our assessment is very positive, but it is in no way sufficient to look only at department level if one wants to advance in excellence. To strengthen and explore intra departmental links have a very high potential and in view of the real needs of society this should be used to the utmost. Production is a very important area for value creation, value that is not only to optimize the profit of a few but is to sustain the people connected with this work and beyond.

In view of the societal relevance of the knowledge accumulated in IIP regarding real production processes and in view of IIP's acknowledged strength measures should be defined to safeguard this knowledge beyond reorganization or upcoming retirement events of senior faculty.

In a first step the departments should try to sharpen their cooperation for this goal on a bilateral basis, between two departments. Formulating strategic goals for society, for which the departments want to supply clear scientific answers that are immediately applicable for Swedish production based on the complementarity of their respective expertise. Buzz words are not admitted. Then this discussion can be broadened until it includes all departments of the school. This will be a tedious exercise as it

demands real and unbureaucratic cooperation. The scale of success is reaching industrial reality and improving measurably value creation. Growing excellence will be the award as it not only will attract high potential students but also external willingness to supply new funds for research. The example of Scania can lead the way.

At the same time KTH has to provide evidence that its administration is apt to support this. The organization backing up this endeavour has to be agile, and in a position to react quickly to new research opportunities. Such new research opportunities are not simply a topic like e-mobility but they have to show that they deal with all aspects of such a new topic that are of relevance for society (e.g. material availability, conditions of material supply, extensive research on boundary conditions of the new technology).

7. Final remarks

IIP is encouraged to tune its role in the concert of the school's departments which means to bring its scientific answers for digitized production processes into accord with mechatronic solutions and precision engineering, specific work that might even be carried out at other places of the school. Only with a cooperative interdisciplinary approach of all departments of the school can all and therefore each department serve the continuously increasing importance of socio-economic interfaces.

(As the faculty of KTH has turned the international regulations to provide BSc education in Swedish will lead with time into an impossible, unfair situation. The Swedish speaking faculty members will become overloaded with BSc education, while the non-Swedish speaking professors and lecturers can completely skip the BSc education duties. Such language related regulations need to be changed! This might require legal changes.)

Message to KTH top management: KTH needs to develop a fair, transparent process to finance research infrastructure. Investment intensive departments, such as IIP, are typically short of recent technologies. It is recognized that there are always many urgent needs for financial resources, but there have to be fair procedures to deal with the prioritizing.

Department of Machine Design

Major findings

1. Strengths and weaknesses of the department

MMK is a well-established, research excellent, well-functioning and very well-led Department; with a coherently working management team, exceptionally strong, wide, and long-standing research collaborations, substantial infrastructure, workshops and labs, the highest ratio of external funding to internal base funding within KTH, at 2.5 times external funding per base funding, and outstanding research-informed teaching successfully mobilised as impact pathway. MMK is strongly positioned via its relevance, with an outsized impact today and in the future on individuals, organisations (industry, public organisations, joint), and, by extension, society. Core research expertise includes keywords listed in alphabetical order: cyber-physical systems; design; innovation; machine elements; mechatronics; model-based engineering; product development; tribology.

MMK has grown 40% since RAE 2012, with increases in educational funds and external funding, without a complementary growth in its physical infrastructure. During the panel interview conducted on 24 August 2021, MMK leadership had a thoughtful perspective on this and its necessary evolution – synergy between education and research; synergy with other Departments; and becoming more computational in nature rather than with a larger physical footprint. Repurposing of the Internal Combustion Engine infrastructure and other space savings has allowed further infrastructure efficiency. The Department is very well-positioned to develop concepts relating to lab in pocket, prototyping labs and workshops as collaborative inward-connecting and outward-facing hubs. The self-evaluation report reflects a healthy combination and awareness of application-orientation and research rigour, evidenced in sources of funding – industry versus competitive grants; publication targets – journals versus conferences; nature of the faculty – tenured versus non-tenured/adjunct. Despite MMK's outstanding success in external research funding and publications in highly ranked journals, it appears at the same time built upon a small number of key individuals. And, as we learned in the interview, with no explicit plans for new faculty hires as yet, it requires heightened emphasis on continuous development and prospects creation of current staff, potential redistribution of teaching- and other duties, and active mentoring for the next generation of Department leaders. MMK seems to have an organic process to ensure this, and we commend them for this.

It is obvious that there are numerous pockets of excellence within MMK. To develop, we encourage the Department to work on visibility as a whole, to accentuate how the focused parts come together to reflect the uniqueness of MMK as a whole, to clearly connect to and position the Department and its divisions within the national and international peer-research landscape, and to emphasise scholarship. There is a real opportunity to do this, as MMK re-organises for the future. This might be in the form of a Department-level roadmap for the long view. Finally, MMK's strategy to leverage centres such as ITRL and large programmes such as TECoSA to shift towards a focus on complex, dynamic socio-technical systems is very exciting. We recommend the Department to consider a higher order “system of interest and impact” (e.g. smart cities; urban/climate resilience), building on expertise in all four Divisions and perhaps also in collaboration with colleagues from policy, law, and business. Along these lines, we recommend that the Department reconsiders if the name MMK truly represents them as an appropriate platform going into the future and increasing its outreach to society.

2. Relevant and forward-looking objectives

The recognition that MMK is postured positively with regard to many of the technological trends in play and a clear alignment with sustainability goals is correct. Given the depth of the faculty in System and Component Design; in Mechatronics and Embedded Systems; in Integrated Product Development and Design; and in Internal Combustion Engines (evolving), their statement to “*aim to build on the systems thinking and systems engineering knowledge developed at all units at MMK and explicitly*

underpinning the research approach at Integrated Transport Research Laboratory to establish a new or enlarged unit focusing on complex dynamic systems” is very credible, robust, and forward-looking. There is a thread throughout the self-evaluation of MMK building strong internal and external bridges. This will require future leaders and research faculty and staff that are able to leverage these bridges to manage ever-stronger collaboration and cross-disciplinary projects, and this is also explicitly recognised as a goal.

3. International community engagement

Faculty and staff within MMK have a stable and enduring set of international collaborators. 50% of all MMK publications are co-authored with international colleagues. A number of current professors within MMK take leadership roles as editors, in international research networks and societies, and have served as visiting professors at international universities. For example, Associate Professor Jennie Björk is Editor-in-Chief for the journal *Creativity and Innovation Management*; Professor Glavatskih has been visiting professor at Ghent University (Belgium) and at University of New South Wales (Australia); Professor Magnusson at LUISS Business School (Italy); and Professor Törngren at UC Berkeley and Stevens Institute of Technology (USA). Professor Törngren is also a leader on a number of EU projects on cyber-physical systems, while Professor Magnusson is the President of the Continuous Innovation Network. This engagement with international colleagues goes beyond individual faculty and involves specific initiatives also across a number of the divisions.

4. Future potential of the department

MMK's future relevance is robust and with the proposed initiatives and goals identified in the self-evaluation, very exciting. Leveraging the disciplinary depth and rigour within the four divisions of MMK, together with a role as system architect for KTH, and a desire to focus on complex and dynamic socio-technical systems should result in long term impact on society. It is exciting to see aspects of rigour and creativity in equal measure in the self-evaluation. The identified goals also position MMK along a strong vector of alignment with the strategy of ITM and KTH.

5. Recommendations

Building on recommendations listed in Section 1 above, the panel recommends MMK to capitalise on, explore and exploit their infrastructure and labs as hubs. A number of research divisions within MMK have creatively leveraged the infrastructure of its industrial partners to enhance their research footprint. Given that there is now a focus on research and teaching infrastructure, perhaps MMK can develop an explicit “industry as laboratory” concept in selected areas of expertise. Moreover, as MMK shifts towards the future – in terms of focusing on socio-technical systems, complex dynamic cyber-physical systems, and systems engineering and systems thinking more widely – with clear synergies in expertise from all Divisions, we recommend that they reconsider the name of the Department with a focus on representing the brand of MMK with greater clarity about its focus, and its great potential for even stronger impact on society. The panel also recommends a Department-level road mapping exercise to develop a coherent picture of how the different areas of excellence within MMK fit together and will evolve synergistically in the future. Finally, we recommend a concerted effort to improve the research output of MMK in the form of journal and refereed conference papers and engagement with the community at the relevant conferences.

Specific issues

1. Research profile and quality

a. Central research questions and themes, and main research activities

MMK with its currently four divisions and research groupings within the divisions covers multiple research topics, with an overall alignment on tackling sustainable futures and digital transformation. The research topics show a strong industrial and societal relevance overall and position the Department prominently in tackling future challenges. A core activity and success to-date is the Department's track record in raising external funding, further evidencing industrial relevance. Another core activity is the Department's role and reach in educating engineering leaders of the future, including running of the labs and workshops that link research, education, and societal outreach. MMK's decision to discontinue the Internal Combustion Engine division, and instead repurpose its resources towards the development of its thematic focus on complex, dynamic socio-technical systems with an initial focus on transportation, given the platform offered by ITRL; along with the newly awarded TeCOSA initiative on secure edge computing, proves its leader's excellent disposition to adapt to future needs.

b. Contributions to the advancement of state of the art within the research fields of the department

The excellence of the research at MMK needs to reach a higher level of visibility. We advise to progress a clear and robust publication strategy across the Department. A focus on this in the coming years will have a significant impact on the profile of MMK beyond KTH and Sweden. Furthermore, robust participation at the relevant conferences will also support the recruitment efforts within MMK in conjunction with its evolving focus on complex systems.

c. Quality and quantity of contributions to the body of scientific knowledge, engagement in national and international research collaboration within academia and its outcomes

There are perhaps two ways to consider this - the past and today; and then in the context of the shift towards a socio-technical systems context in the future being considered by the faculty and staff within MMK. If we consider the past and today, the quality of research and scholarship within MMK is unquestionable. The gap as we see it is the translation of this excellence into a robust publication record that reflects this authentically, along with engagement at the international levels in the relevant academic communities. This can and should be emphasized and improved. Further, when considering the future shift towards a more complex socio-technical systems context, the global research and academic community can benefit from a more active MMK/KTH engagement. It would be wonderful to see more of our academic colleagues at KTH in leadership roles with the top journals and societies in this space - while being good for MMK and KTH, this would be welcomed on the global stage.

d. Follow-up from previous evaluations

RAE 2012 recommended MMK and ITM to tackle grand challenges, in particular sustainability, and also school-wide collaboration and cross-disciplinarity. The recommendations have been followed, with the IRIS initiative as the core response and the Department's emphasis on research centres, bringing together researchers across KTH. Overall, MMK's cross-departmental collaboration has increased and sustainability is addressed very strongly. Given this track record, it might be time to focus on a higher-order society problem where MMK can make a significant contribution, and build external bridges to disciplines such as economics, policy, and law - with a focus on application domains like healthcare, urban resilience, and smart cities.

2. Viability and research environment

a. Internal and external funding; current status and strategies for the future

MMK is very strong in attracting external funding. As a whole, the funding of MMK has increased by 40% which is a great achievement, with increases in educational funds and external funds and without a complementary growth in its infrastructure. MMK has the highest ratio between external funds and basic university funds than any other department at KTH at 2.5 times external funding per base funding. At the time of RAE2012, this ratio was 1.3. The ratio of external/internal funding varies greatly between the divisions. Is this ratio satisfactory? The level of internal funding is relatively low (we understand this is a subject-matter discussion beyond Department-level). However, as externally funded projects, e.g. EU grants require seed funding internally, this may require creative ways of raising and flexibility in allocation of (internal) funding in going forward.

b. Academic culture

While this was not articulated explicitly in the self-evaluation report, from our interview with the MMK team, a strong collaborative culture and commitment was clearly and easily recognisable, with a shared focus on excellence and impact. The robust impact of MMK via its leadership of 5 of the 7 ITM level centres reflects its collaborative culture, along with its plan and capabilities for fostering an ITM-wide prototyping culture. The Department has also developed an internal mentoring and leadership program to ensure future leaders within MMK, and that is commendable.

c. Current faculty situation and composition of the research team(s)

MMK faculty covers 85 employed and affiliated faculty, plus 55 doctoral students (32 employed, 19 industry affiliated, 4 scholarship third cycle), and a reach to more than 1000 students through first and second cycle education. Faculty currently includes 8 professors (6 male, 2 female), 13 associate professors (10 male, 3 female), 2 assistant professors (1 male, 1 female), 4 lecturers, 3 post-docs, 31 researchers, and 10 adjunct/affiliated professors. The Department is composed of (to-date) four divisions and five centres. The divisions are: Integrated Product Development and Design, System and Component Design, Mechatronics and Embedded Systems, and Internal Combustion Engines (to be phased out by October 2021), and with plans for a Complex Dynamic Systems division. The number of staff and gender composition varies across the currently four divisions. Relative distribution of early-, mid-, and advanced career and alignment of positions and actual work portfolio might need revisiting. As a whole, there is awareness of gender balance in going forward and it is described as a core point for further staff recruitment. It might be beneficial to think of inclusivity and diversity also with respect to internationalisation. The notion of tenure track applied might need clarification, esp. for international recruitment.

d. Recruitment strategies

Recruitment procedures are according to Swedish law and regulations and KTH guidelines. The ambition is to have all permanently employed staff (the self-evaluation report presumably means academic staff) in tenure track positions. The MMK leadership conducts their recruitment through nurturing their very best doctoral students and targeted outreach to other universities. This approach has to-date been effective.

e. Infrastructure and facilities

Many research- and educational activities require physical infrastructure such as laboratories and workshops. MMK also hosts a prototyping centre that supports KTH-wide and other research partners outside the university. MMKs infrastructure expenditure is at the same level as during the time of RAE 2012 - even though research activities and funding have grown by 40%. This shows great effectiveness by the Department. The plans to move from heavy, general purpose facilities into dedicated, flexible laboratory facilities and to increase synergies with educational programmes and courses for both

research and teaching are wise. Here, a potential expansion and opening of the prototyping centre as well as strengthening capability in digital prototyping in its widest sense and together with other units in the Department and across KTH are encouraged; for use in research, education, and outreach in industry and other organisations through continuing education.

3. Strategies and organisation

a. Goals for development 5–10 years ahead

The plan for the coming 5-10 years holds a number of options. On the one hand, core technical research areas might experience radical disruptions (e.g., combustion engines). On the other hand, there are alternative and complementing scenarios under development with digitalisation and sustainability as key drivers for change, including the move to transformational framing towards complex socio-technical systems, and thereby leveraging and building on research in all of the divisions. As mechanics are still needed in products and also cyber-physical systems also in the future, the panel encourages to build on the strong technical core and expand to branding in the frame of design and development of sustainable solutions, thereby investing in the vision of a complex socio-technical systems frame more widely. This would set MMK more clearly on a more ambitious pathway to internationally visible research leadership. Explicit focus on enabling and developing future research leaders will be one of the core priorities ahead. To facilitate this goal, we would recommend that MMK/KTH consider a new professor position focused on complex socio-technical systems to help with the acceleration of this shift.

b. Congruence with university-level goals

KTH aims to be positioned as a leader in a world that is increasingly driven by digitalisation and sustainability challenges. MMK is with its research emphasis on the future development and role of industrial systems with new challenges, including technical (e.g. more controllable, adaptive machine components) and socio-technical challenges for safety and security, availability, affordability, and accessibility and with its planned strengthening of research into designing new business models and digital transformation well aligned and with and instrumental to fulfilling university-level goals. MMK furthermore underlines collaboration and platforms to tackle cross-disciplinary challenges.

c. Leadership structure and collegial structure

There is a strong sense of community and collaboration within MMK. There is a shared aspiration for societal impact, excellence, and creativity. MMK staff realises that they are a team, co-creating a very good and well-led Department, and they are careful to nurture their culture.

d. Strategies for achieving high quality

MMK appears to count on peer-review of articles as this is the basis for how (national) funding is awarded. This is a pragmatic starting point, yet relies on good intentions of reviewers and further, being awarded funding does not necessarily guarantee high quality research and international visibility. The panel advises to explicitly focus on ongoing scholarly development practices and increase the quality of articles, e.g. through mentoring and training in article writing and awareness of disciplinary positioning of target outlets.

4. Interaction between research and teaching

a. Interaction between research and teaching at all three levels (B.Sc., M.Sc., Ph.D.) of education

There is clear commitment to research-informed teaching as an impact pathway for building engineering leaders for the future. MMK hosts two large master programmes with staff from all four

divisions involved. There are multiple direct links between research and teaching at all levels, and particularly towards the final year of the undergraduate and graduate degrees (capstone courses, final year theses). MMK is recommended to explore and experiment with means to connect students with departmental research projects also in earlier stages of their studies. Earlier involvement would also increase the attractiveness of research careers for MMK students. The Department might explore opportunities to strengthen courses for PhD students on scholarly craft development.

5. Impact and engagement in society

a. Relevance, scale, and impact of the department's current engagement with society and industry

Research at MMK is strongly applied in industry and public organisations, with long-lasting collaborations and related external funding, evidenced also by a high number of adjunct and affiliated professors. Impressive impact cases in the self-evaluation report are further testament to high societal relevance and strong impact. For example, the KTH Mobility Pool on Sustainable Transport, with wide media uptake and the implementation of a car-pool set-up in a municipality, functions as catalyst for new projects, development of sustainable mobility solutions and connects to future plans on an integrated transport lab, with huge potential for capitalising on the links between system-led design, human behaviour, and innovation ecosystems. Another example is life expectancy in urban areas with research from the Department on emission reduction in a three-fold manner: reducing emission from disc brake, tyre-to-road wear emissions, and airborne emissions. Results include patents and integration of research in application sectors transport and health, underlining the commitment to the UN SDGs. The aforementioned examples emphasise the strong opportunity to move towards a more system-oriented framing of the research areas in all Divisions contributing. Combined with the strong infrastructural set-up, MMK is thereby clearly serving academia, industry, and society and a central pillar for KTH's goal of impact through collaboration.

b. Research dissemination beyond academia

The applied nature of the research at the Department has close interaction with industry and public organisations at its core. Collaborative research listed in the self-evaluation report includes a number of leading companies, e.g. Husqvarna, Sandvik Coromant, Scania, BMW, as well as with the Swedish Police and the Swedish Defence University. The impact cases included patents and coverage in national media. In line with societal developments, a more explicit strategy and actions to include social media posts in the research dissemination strategy might be worth exploring, provided in-line with university policy.

c. Relation to sustainability and the United Nations' Sustainable Development Goals (SDGs)

The self-evaluation report states boldly that 100% of the research performed at the Department relates to the SDGs. To-date, emphasis lies on SDG 7 (Affordable and Clean Energy), 9 (Industry, Innovation and Infrastructure) and 11 (Sustainable Cities and Communities). It would be interesting to explore the interactions between- and nestedness of the SDGs, in particular given the move to a stronger accentuation of system-led research. Further, it would be interesting to elaborate on what is meant by 'relates to'. Going beyond goal level to indicators and targets? Using the goals as vision for long-term research programmes? There is evidence that MMK is going in that direction, as highlighted also in the interview with the panel, for example through contributions to sustainable development with the '*centres as spines*'. Here, research expertise across the Department is pooled, with research results to-date making substantial contributions to improved use of renewable fuels, intelligent automation leading to flexible, secure and resource-efficient manufacturing and transportation systems, and business model innovation and servitisation, enabling the design of shared- and circular economy.

d. Plans and structure for increased impact

The Department builds on its pedigree and strong legacy of close and long-term research-based collaborations with partners from industry and public organisations. MMK counts primarily on its reputation and networks to create industrial and societal impact. This long-term nurture and development of partnerships is highly commendable. Additionally, to maintain attractiveness forward and to increase research visibility, MMK might want to consider new impact pathways more systematically and strategically (see also dissemination beyond academia).

6. Recommendations for strengthening the department and its future potential

MMK is a strong and robust department that is having a significant impact today via its students and sponsors/partners, with a significant potential for a higher impact in the future. With a view towards this future, and MMK's consideration of an enhanced focus on socio-technical systems, complex dynamic cyber-physical systems, and systems engineering and systems thinking more widely – with clear synergies in expertise from all Divisions – we recommend that they reconsider the name of the department, and the internal divisions and their boundaries with a focus on representing the brand of MMK with greater clarity about its focus, and its great potential for even stronger impact on society.

We recommend that MMK consider a higher order objective to impact society. The panel sees this as a possible game changer in achieving recognition at outstanding levels of society and the academic community. An example might be a focus on “smart cities” or “urban/climate resilience.” This would leverage the core strengths in ITRL and TeCOSA, and would cause MMK/KTH to consider focused bridge building to other disciplines such as economics, policy, and law, and support the evolution of MMK/KTH along the vector of truly socio-technical systems, with a focus on engineering design and science as a core dimension. Along these lines, we recommend that MMK/KTH consider a new professor position explicitly focused on complex socio-technical systems.

We recommend the MMK capitalise on, explore and exploit infrastructure and labs as hubs - this is strengthening of selected initiatives underway already, and will support deeper collaborations across KTH. A number of research divisions/groups within MMK have creatively leveraged the infrastructure of its industrial partners already. Given this experience, we recommend that MMK develop an explicit “industry as laboratory” concept in selected areas of expertise. This will allow an even deeper collaboration with their research partners in industry and government.

The panel also recommends a Department-level road mapping exercise to develop a coherent picture of how the different areas of excellence within MMK fit together and will evolve synergistically in the future. This will also support a more explicit investment and growth strategy for the administrative leaders within MMK and KTH.

Finally, we recommend a concerted effort to improve the research output of MMK in the form of journal and refereed conference papers and engagement with the community at the relevant conferences.

7. Final remarks

Overall, it was a pleasure to review MMK. We see a department with a terrific legacy, but not constrained by it, as reflected in its future plans. The MMK culture and a shared mental model of a focus on relevance and excellence and impact is very visible in the self-evaluation report, and through the interviews with the faculty and staff. If anything, our recommendations allude to its potential for an even bigger impact in the future.

We have two recommendations with regard to relevant materials for analysis and observations. First, it would be good in the future to have a stronger and cleaner correlation between the material on the website and the content of the self-evaluation reports. Second, it would be desirable to have more up-to-date and correct data with regard to the publication records of faculty and research staff. However, these two items may not be department or school-specific, but regard the broader KTH-level.