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Research Paper

Dynamic System Analysis of R&D Based on Localization Capabilities in the Commercial Auto Industry

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Abstract **T According to published reports on the level of internalization of commercial vehicles, it shows that most carmakers pursue a minimal domestic manufacturing policy and less have a policy of increasing domestic manufacturing on their agenda. The most important research gaps are need to study R&D activities in the form of a dynamic system in the automotive industry based on the three variables of supply network capabilities, product innovation and process. The purpose of this study is to provide a dynamic model to investigate the behavior of a commercial vehicle R&D system. The present study is applied in terms of purpose. The basis of the system analysis is previous research as well as information obtained from interviews with automotive industry experts. For this purpose, first the variables affecting the cycle of R&D activities are studied and modeling is presented using the dynamics approach. Also, various policies on the performance of the development research cycle based on the time of knowledge acquisition and product introduction have been simulated and analyzed. The results of system performance simulation show that the weak share of research and development budget along with low and limited market share and lack of proper investment makes the research and development capability at an unfavorable level during the next 10 years. Therefore, it is suggested that the necessary**

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measures in this regard be taken in the fields of product sales marketing along with appropriate investment in research and development.

Keywords *R&D, Localization Capabilities, System Dynamics, Automotive Industry*

Introduction

R&D is a dynamic and interconnected process of basic research, applied research, and developmental research, the practical results of each stage is a reserve of knowledge for creating products and processes (Aníbal and Gonzalo, 2017). These reserves are regarded as a significant and valuable input, as well as the source of new ideas and inventions (Latipova, 2015). R&D refers to the discovery of new knowledge about products, processes, and services and the use of knowledge for creating new and developed products, processes and services, covering the needs of the market (Kaisa et al., 2016). Based on endogenous growth models, technological advancement and R&D are recognized as the engine of growth (Aníbal and Gonzalo, 2017). The point is that turning to R&D without creating the required infrastructure including human resource capabilities and organizational strategies lead to the failure of the R&D process of enterprises (Yan, 2018). The automotive industry has become a global industry over the past decades. On the other hand, this globalization has caused new competitive conditions and an international approach to complete the value chain in this industry (Shah Hosseini et al., 2017). The automotive industry has the largest share of R&D costs among all industries after the computer, electronics, and health industries .Investment in R&D in the global automotive industry in 2018 was equal to 98.2 billion dollars with a growth of 1.5% during the previous year. Based on the World Automobile Manufacturers Association, the amount of investment in R&D in the global automotive industry in 2018 was equal to

98.2 billion dollars with a growth of 1.5% during the previous year (Szmigiera, 2021). It should be noted that the R&D of new products is one of the most critical sources of creating a competitive advantage with the complexity and globalization in the competitive business environment . On the other hand, strengthening R&D in the automotive industry has had a significant effect on increasing profit margins and sales of companies (Dorota and Dorota, 2016). In general, improving and developing the current products, having access to new technologies, accelerating the introduction of a new product, and limiting strategic risks are among the strategic R&D strategies (Barragán and Zubieta, 2018). The cost of automotive companies for R&D is not clear well. About 1-3% of the turnover of domestic automakers is spent on R&D and most of the funds as new product development projects are allocated to large automotive design consulting companies and their collections (Abedi and Oryani ,2016). In addition, the ratio of R&D to value added in the Iranian automotive industry during the past years has been 1.2% and the ratio of value added to production has been 0.3% on average, indicating insufficient attention to R&D in this industry .Meanwhile, the place of the automotive industry in the economies of countries is significant. The average share of value added in the automotive industry in the industrial sector is 12%, the share of employment is 15%, and 3% share of the gross national product are among the features of this industry (Abedi and Oryani ,2016). The following objectives are pursued:

- Identifying the effective factors in the R&D activities cycle
- Studying the behavior of each main variable studied in the model
- Analyzing the decision-making scenarios by simulating the behavior of variables

Literature Review

Yan(2018) in his study entitled “Relative adaptation to R&D” provided a framework for examining the dynamics of firms in relation to the R&D intensity. Firms normally fail to adjust to the intensity of their R&D directly or completely. In addition, they consider half of the gap between past studies and development intensity and their goal in a year. Shah Hosseini et al.(2017) studied the role of strategic alliances on the R&D intensity in the Iranian automotive industry with a networking approach. Aníbal and Gonzalo(2017) in their research entitled “Classification of R&D projects and selection of R&D project management type” stated that the dispersion and variety of methods for evaluating the capabilities of R&D project and their classification cause some problems in selecting an appropriate right management concept for the R&D project. Samadi Moghadam et al. (2017) studied the importance of R&D capabilities on technology transfer methods in investment. Ghasinoory et al.(2017) investigated the factors affecting the cost of the Iranian business sector in R&D activities. Coyle and Exelby(2000) examined the effect of R&D spending on firm value. The considered criteria are R&D intensity, as well as R&D capabilities. Juliana et al.(2011) studied the effect of R&D capabilities on competitive market share. Hans (2003) examined the effect of revenue sharing on new product development performance with an emphasis on the role of R&D team. Meade and Presly (2002) studied the design of R&D systems in large companies by examining the revenue share and examining a model for planning and controlling R&D activities. Kaveh et al. (2020) in their research entitled “Marketing Strategy Evaluation by Integrating Dynamic Systems Modeling and Network Data Envelopment Analysis” developed appropriate marketing strategies in the form of scenario-based strategic planning in the life insurance market of Mellat Insurance Company. For this purpose, system dynamics and network data envelopment analysis tools have been used. In order to formulate marketing strategies, the causal-loop diagram and then the flow-stock diagram were simulated for scenario-based strategic planning. Thomas et al. (2013) evaluated R&D and its effect on performance. In this study, the relationship between R&D capabilities and sales share obtained from several R&D indicators was considered. Arun et al.(2002) studied the effect of investment on R&D in the performance of companies. In this study, he compared the effect of investment on R&D on revenue share between American and Taiwanese companies. Latipova(2015) evaluated the effect of sales on R&D. The results of this study indicated the positive effect of sales on R&D. Daim et al.(2017) examined the effect of R&D and capital on unrealistic pricing (pricing below the real price) of high-tech products. In this study, they considered the uncertainty of data as an effective factor in pricing. In fact, this uncertainty of data and the lack of information cause pricing to be lower than usual. Barragán, and Zubieta(2018) in their study entitled "Cooperation in industry and success at the university level" evaluated the moderating effect of product and process innovation and mutual cooperation between companies. Such a cooperation based on science or market is a useful tool for R&D groups to use additional expertise and resources to produce innovative results. Zolaikhaei and Radar(2020) in their research entitled "A System Model for Technological Capabilities Assessment in High-Speed Train Industries" studded to provide a model with a dynamic system method to investigate the factors affecting the technological capabilities enhancement in the high-tech industries of high-speed train of the rail transportation system. Based on the obtained results, variables such as having a suitable vision for technology development, recognizing basic technological priorities, ability to use and control technology effectively in main and support processes, ability to learn from one technology to another, ability to identify, evaluate, negotiate and finalize the terms of technology acquisition and support facilities, the ability to identify customers, announce auction prices and negotiate terms of sale, the ability to plan, monitor and control research and development projects and having a proper system for evaluating technological projects, have great impact. Félix et al.(2017) studied the factors affecting R&D in industrial companies. In their study, they evaluated the competitive and internal factors of the organization. In this study, they analyzed seven basic factors, among which process innovation and product innovation are the most significant and most influential factors in the development of R&D in organizations. Jung and Seo(2010) examined the effect of R&D as well as supply network capabilities on the export decisions of Japanese companies. The results of this study indicated that the capabilities of the supply network and product innovation have a significant effect on cooperation with companies and international cooperation on companies' export decisions. Peyvasteh et al.(2019) in their research entitled “Technology Assessment Model with Dynamic Capabilities Approach in Small and Medium Enterprises” Have expressed in the technology-driven industries like automotive industry, the success of the companies depends on their ability to provide new and continuous innovations to the market. In this regard, technological capabilities lead to a competitive advantage. Juite(2017) identify the effective factors in the technology assessment based on the dynamic capabilities of small and medium automotive supply chains. In this study, by using the principal components analysis (PCA) method, the identification of the important factors according to the views of automotive industry experts has been addressed. The results show that from the perspective of dynamic capabilities, Absorbency and learning, Innovative capability and integration capabilities are the most effective factors. Kaisa et al.(2016) in their study entitled "Management of appropriateness of product innovation cooperation and supply network capabilities" mentioned that R&D cooperation with different types of external stakeholders for companies pursuing innovation-related goals increasingly becomes important. However, the cooperation with the actors such as customers, suppliers, competitors, and research organizations has caused some risks related to supply network capabilities leak and potential misuse of value. The table below summarizes the foreign and domestic studies on R&D. Studies indicated that no framework was provided in the dynamic modeling of R&D activities based on supply network capabilities, product innovation, and corporate process.

Table1.
Studies Associated with R&D Related Variables

References	**R&D related variables**
Peyvasteh et al.(2019) ,Yan (2018), Shah Hosseini et al.(2017), Ghasinoory et al. (2017), Huang et al.(2008), Thomas et al. (2013)	RD Intensity
Zolaikhaei and Radar.(2020) , Aníbal and Gonzalo(2017), Samadi Moghadam et al. (2017), Ghasinoory et al.(2017), Dorota and Dorota(2016), Juliana et al.(2011)	RD Capabilities
Juliana et al.(2011), Hans(2003), Meade and Presly(2002), Thomas et al. (2013), Arun et al.(2002), Latipova(2015), Daim et al. (2017),	Revenues Share
Barragán and Zubieta(2018), Martha et al. (2016), Linton et al.(2000),	Process Innovation
Kaveh et al.(2020) , Barragán and Zubieta (2018), Yu(2017), Gasbi, and Chkir(2016)	Product Innovation
Jung and Seo(2010), Kaisa et al.(2016)	Supply Network Capabilities

Method

The present study was descriptive-modeling in terms of objective, application, and research method. The basis of system analysis is previous studies, interviews with experts, and the information obtained from interviews with automotive industry experts. A number of 50 experts were selected in this study. Some of the main features for selection are work experience related to the automotive industry, master's degree and higher, and a history of executive management in R&D. Furthermore, the existing studies have tested the hypotheses of R&D in the form of a single variable, and most of the studies have a qualitative approach. The need to investigate R&D activities in the form of a dynamic system in the studied industry based on the performance and use of modern scientific methods of data analysis is one of the most significant research gaps. Thus, the dynamic modeling of R&D activities based on knowledge gained from experts can be regarded as necessary.

Findings

Causal Loop Diagram

- Loop 1: R&D Intensity can also be recognized as a factor contributing to increasing product innovation in the parent firm. As the R&D intensity increases, the number and volume of new product development projects may also increase accordingly in the parent firm. The increase in new product development projects can, in turn, lead to a decline in the number of learning and design, engineering, and manufacturing cycles (Oliver et al., 2019). The factors contributing to rises in the level of product innovation can directly lead to improvements in the R&D capabilities of the parent firm as well as increases in the revenue share which could consequently lead to a rise in the share of R&D intensity.

- Loop 2: R&D Intensity can also be recognized as a factor contributing to increasing process innovation in the parent firm. As the R&D intensity increases, the number and volume of new process improvement projects may also increase accordingly in the parent firm. The increase in process improvement projects can, in turn, lead to improvements in the process innovation level, including vehicle part and assembly localization as well as the quality of the automobile part manufacturing process (Yan , 2018). The factors contributing to rises in the level of process innovation can directly lead to improvements in the R&D capabilities of the parent firm as well as increases in the revenue share, which could consequently lead to a rise in the share of R&D intensity.

- Loop 3: improvements in the supply network capabilities can indirectly lead to improvements in the R&D capabilities of the parent firm. Improvements in the supply network capabilities can also lead to development of product innovation in the parent firm. The high product design and engineering costs make it impossible for firms to implement their product development projects all by themselves. Therefore, the supply network capabilities can play a complementary and contributory role in development of the product innovation. R&D can, therefore, improve the level of technology and consequently innovations that will lead to generation of competitive advantage. On the other hand, technological advances and innovations will reduce design, engineering, and manufacturing costs and consequently benefit competitiveness and profitability. Cooperation opportunities increase across the supply network, improving the scale of production scale, and this can, in turn, contribute to development of economies of scale (Daim et al., 2017). Increase in demand can lead to improvements in profitability, investment, as well as R&D activities, and this cycle keeps repeating itself.

- Loop 4: improvements in the supply network capabilities can indirectly lead to improvements in the R&D capabilities of the parent firm. Improvements in the supply network capabilities can also lead to development of process innovation in the parent firm. The relationships between the variables as well as the feedback structure is presented in form of a causal diagram as follows.

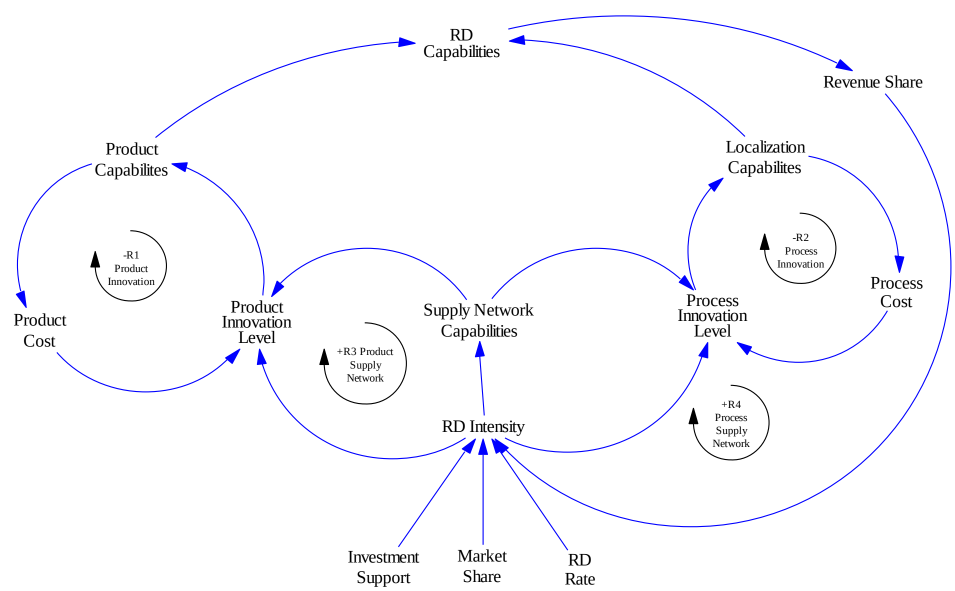


Figure 1. Causal model of R&D cycle

As can be observed in the above figure, four causal loops are considered in the conceptual model.

Model formulation includes Stock-flow maps and mathematical equations. Graphical representation of the problem contributes to conceptualization of policy structures. For computer simulation of the model in these diagrams, however, it is necessary to convert them into mathematical equations. To this end, stock-flow models for each of the variables are formulated according to the relevant literature, the causal diagrams presented in the previous sections and the expert judgments. The proposed model embodies all the relationships between the variables affecting the R&D cycle with respect to the scope of study and the formulated assumptions. The detailed stock-flow diagram of the R&D cycle is presented below.

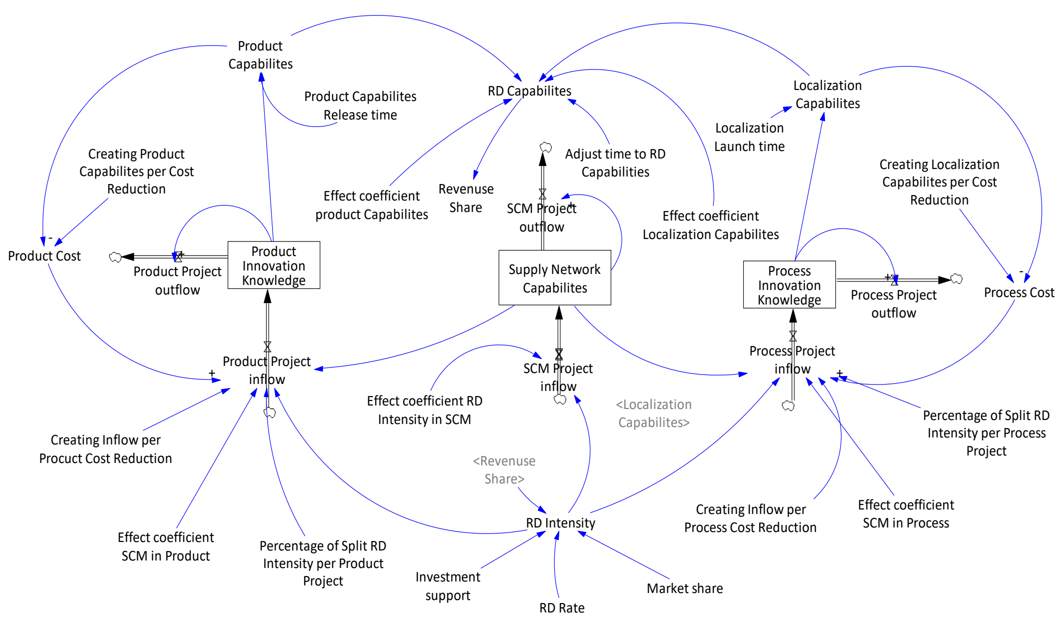


Figure 2. Stock- flow modeling in the R&D cycle

Based on previous studies, the R&D intensity can affect the rate of definition and implementation of supply network capabilities development projects. The rate of definition and implementation of parts localization projects and process engineering and product components depends on different factors. Based on the conducted studies, the budget of process development projects depends on the R&D intensity, the capabilities of supply network, domestic part manufacturing companies, and finally the reduction of direct cost resulted from the implementation of process development projects. Process development costs are another variable which has been defined in this cycle. Engineering costs and process design lead to the localization of parts. The cost of engineering and product design reduces per percent of the level of localization. Based on the conducted studies in Iran, the R&D intensity, the ability to internalize parts and subdivisions, and the ability to develop new products as a network should be created simultaneously to conduct R&D in the commercial automotive industry. The time of absorbing localization, the time of matching the R&D capabilities and the time of presenting a new product to the market are regarded as auxiliary variables for modeling.

Table 2.

Definition of Some Modeling Variables

Variable	**Index**
Rate	Product Project inflow
Rate	Product Project outflow
Rate	Process Project inflow
Look-up	Investment support
Rate	Process Project outflow
Rate	SCM Project inflow
Auxiliary	Localization Capabilities

Variable	Index
Rate	SCM Project outflow
Stock	Revenues Share
Look-up	Market share
Look-up	RD Rate
Auxiliary	RD Capabilities
Auxiliary	RD Intensity
Auxiliary	Product Capabilities
Stock	Supply Network Capabilities
Data	Creating Inflow per Product Cost Reduction
Data	Percentage of Split RD Intensity per Product Project
Data	Percentage of Split RD Intensity per Process Project
Data	Localization Launch time
Data	Adjust time to RD Capabilities
Data	Product Capabilities Release time
Data	Creating Product Capabilities per Cost Reduction

Since the existing equations of the proposed models represent causal relationships, all these equations need to be written on the basis of logical and scientific principles (Daneshzand et al., 2019). In the proposed model, all tests are used to check the validity of equations, design and implementation of the model. Understanding the results of decision making process on various aspects of the problem is one of the main requirements of system analysis (Sterman, 2000). In this section, simultaneous positive changes in the relevant parameters under three scenarios is taken into account for all main variables. Scenarios are effective tools that shape our perceptions of alternative futures; futures that can be significantly affected by our decisions in the present time. Scenario analysis can help us control all the factors that cause future decisions to be associated with ambiguity and provide a logical framework for exploring these factors. Since the present study is an attempt to investigate the R&D cycles and formulate a model for this purpose, a variety of scenarios need to be analyzed in this section.

First scenario (A): Current status

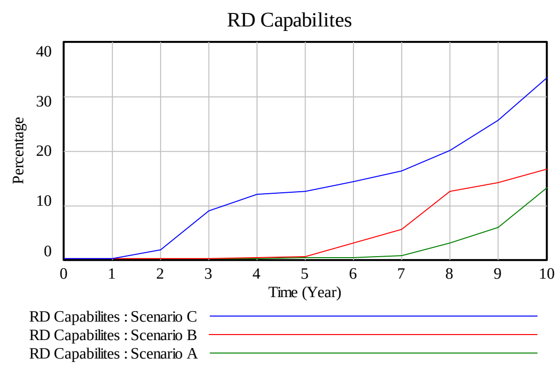
In this case, it is assumed that the R&D rate is 5%, time to acquire the level of localization in the process is three years, time for matching the R&D is four years, and the time required to present a new product is five years. It should be noted that this scenario is the current status of domestic manufacturing companies.

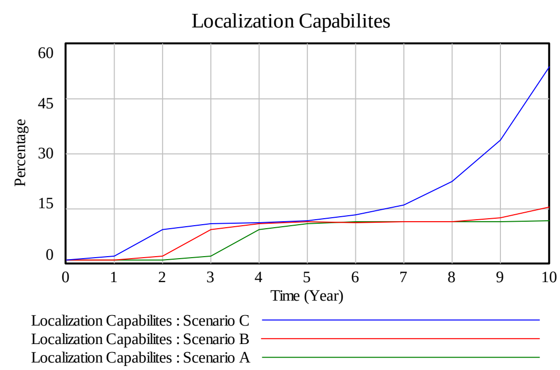
Second scenario (B): Operational status

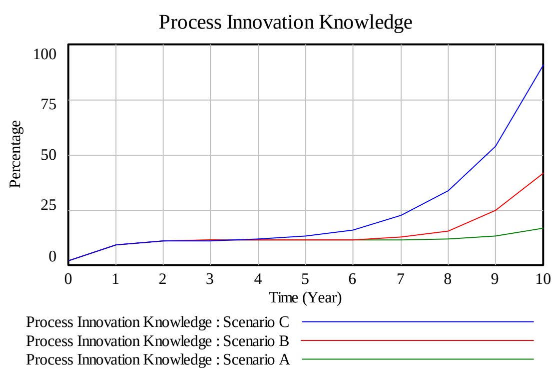
In this case, it is assumed that the R&D rate is 10%, time to acquire the level of localization in the process is two years, time for matching the R&D is three years, and the time required to present a new product is four years. It should be noted that this scenario is a status when sanctions are removed and the status of the presented operational indicators is reached.

Third scenario (C)

In this case, it is assumed that the R&D rate is 20%, time to acquire the level of localization in the process is one year, time for matching the R&D is one year, and the time required to present a new product is two years. It should be noted that this scenario is an ideal goal based on a prospect.


RD Capabilites
Percentage
Time (Year)
RD Capabilites : Scenario C
RD Capabilites : Scenario B
RD Capabilites : Scenario A


Localization Capabilites
Percentage
Time (Year)
Localization Capabilites : Scenario C
Localization Capabilites : Scenario B
Localization Capabilites : Scenario A


Process Innovation Knowledge
Percentage
Time (Year)
Process Innovation Knowledge : Scenario C
Process Innovation Knowledge : Scenario B
Process Innovation Knowledge : Scenario A

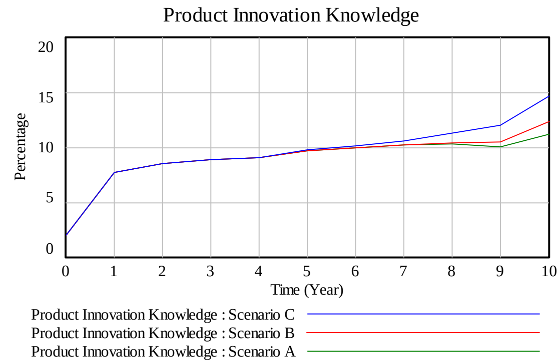


Figure 3. Predicting the behavior of system variables based on the developed scenarios

Analysis of the results obtained from studying the research scenarios:

- Considering the initial defined assumptions and the designed model, the results of the system behavior are observed based on three scenarios such as pessimistic, probable, and optimistic during the next 10 years.
- The R&D intensity increases by 4% based on Scenario A, by 10% based on Scenario B, and by 29% based on Scenario C.
- The level of product localization increases by 12% based on Scenario A, by 15% based on Scenario B, and by 53% based on Scenario C.
- The knowledge of created product increases by 11% based on Scenario A, by 12% based on Scenario B, and by 16% based on Scenario C.

Discussion and Conclusion

Expert judgment was used to examine the developed causal model in terms of product innovation, process innovation and supply network innovation level. The R&D cycle model initiates based on the R&D intensity. The R&D intensity is correlated with the auxiliary variable of investment support (share of revenue from product sales), market share (domestic and export market) and R&D share of cost-benefit in new product development projects. R&D intensity also constitutes an effective factor in three variables namely product innovation, supply network capabilities and process innovation. Process innovation and product innovation can effectively contribute to auto part localization and the product capabilities, respectively. Therefore, R&D capabilities are correlated with product capabilities and localization capabilities. A three-scenario was used to simulate the systemic model.

- R&D capabilities in the commercial vehicle industry are directly dependent on new product development capabilities and localization capabilities. Therefore, it can be argued that development of R&D capabilities calls for capacity building for attracting resources and cycles of technical and engineering learning, design and construction, as well as technological development. Policymakers and executives of manufacturing companies are advised to develop the above-mentioned capabilities within the framework of R&D projects.
- R&D capabilities in the commercial automotive industry is directly related to the time of acquiring localization knowledge, the time for matching R&D capabilities, and the time to present a new product to the market, requiring capacity building in the speed of the accumulation of technical and engineering knowledge. Policymakers

and executive managers of manufacturing companies are advised to pay attention to the factor “duration”.

- The R&D capabilities of the commercial automotive industry is indirectly dependent on the time of acquiring localization knowledge and the time to present a new product, and directly on the time for matching R&D capabilities to adapt to the market, requiring capacity building in speed of operation and agility in operational projects. Policymakers and executive managers of manufacturing companies are suggested to pay attention to the factor “duration”.
- R&D capabilities in the commercial automotive industry indirectly depends on the time to acquire localization knowledge and time to introduce a new product to the market and directly to matching R&D capabilities, requiring capacity building in speed of operation and agility in operational projects. Policymakers and executive managers of manufacturing companies are suggested to pay attention to the factor “duration”.

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